LESSON 1

Describing Motion

When Is an Object in Motion?

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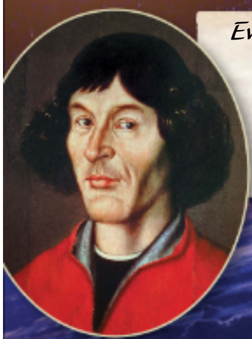
VOICES FROM HISTORY

Nicolaus Copernicus

Why would anyone think that Earth moves around the sun? After all, on a clear day you can see the sun move across the sky. But Polish astronomer Nicolaus Copernicus realized that an object revolving around you from left to right looks the same as an object standing still while you rotate from right to left. In *On the Revolution of the Heavenly Spheres,* he wrote

> *Every apparent change in respect of position is due to motion of the object observed, or of the observer, or indeed to an unequal change of both.*



This book was published in 1543. It was a summary of more than 30 years of Copernicus's studies on the solar system.

Write your answer to the question below.

For thousands of years, many people thought Earth was the center of the universe. Name one possible reason why they thought this.

PLANET DIARY Go to Planet Diary to learn more about motion.

Lab zone Do the Inquiry Warm-Up *What Is Motion?*

When Is an Object in Motion?

Deciding if an object is in motion isn't as easy as you might think. For example, you are probably sitting in a chair as you read this book. Are you moving? Parts of you are. Your eyes blink and your chest moves up and down. But you would probably say that you are not moving. An object is in motion if its position changes relative to another object. Because your position relative to your chair does not change, you could say that you are not in motion.

Vocabulary
- motion
- reference point
- International System of Units
- distance

Skills
- Reading: Compare and Contrast
- Inquiry: Measure

Reference Points To decide if you are moving, you use your chair as a reference point. A **reference point** is a place or object used for comparison to determine if something is in motion. **An object is in motion if it changes position relative to a reference point.** Objects that are fixed relative to Earth—such as a building, a tree, or a sign—make good reference points.

You may already know what happens if your reference point is moving relative to Earth. Have you ever been in a school bus parked next to another bus? Suddenly, you think that your bus is moving backward. When you look out the window again for a fixed point, you find that your bus isn't moving at all—the other bus is moving forward! Your bus seemed to be moving backward because you had used the other bus as a reference point.

did you know?
Because of Earth's spin, the stars appear to move in circular arcs across the night sky. Only the North Star remains in a fixed position. Historically, sailors have used the North Star to help them navigate.

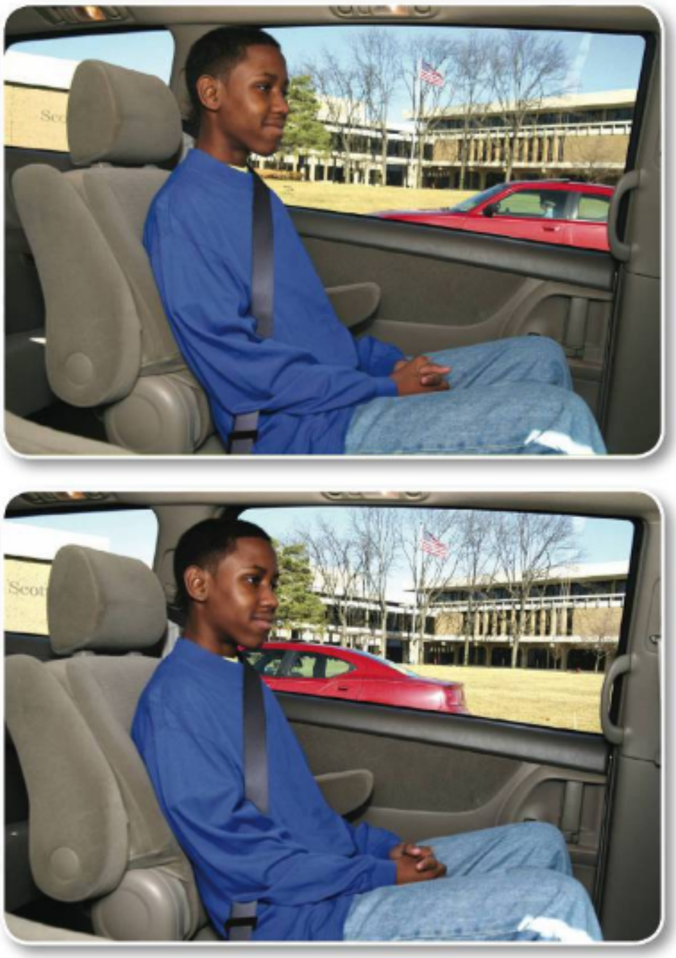


FIGURE 1

ART IN MOTION Reference Point

The top photo was taken shortly before the bottom photo.

Answer the following questions.

1. **Interpret Photos** Did the car that the boy is in move, or did the car in the background move? Explain your answer.

2. **Identify** What objects in this photo make good reference points?

Relative Motion If you use your chair as your reference point as you sit and read, you are not moving. If you choose another object as a reference point, you may be moving.

Suppose you use the sun as a reference point instead of your chair. If you compare your position to the sun, you are moving quite rapidly because you and your chair are on Earth, which revolves around the sun. Earth moves around the sun at a speed of about 30 kilometers every second. So you and everything else on Earth are moving that quickly as well. Going that fast, you could travel from New York City to Los Angeles in about two minutes! Relative to the sun, both you and your chair are in motion. But because you are moving with Earth, you do not seem to be moving.

Compare and Contrast
A tree is (stationary/in motion) relative to Earth. A tree is (stationary/in motion) relative to the sun.

apply it!

The people in the photo are riding on a spinning carousel.

1 Interpret Photos Are the people moving relative to each other? Are they moving relative to objects on the ground? Explain.

2 Explain How is your choice of reference point important when describing the motion of the people?

Measuring Distance

To describe motion completely, you need to use units of measurement. Scientists use a system of measurement called the **International System of Units** or, in French, *Système International* (SI). **Distance** is the length of the path between two points. The SI unit for length is the meter (m). The distance from the floor to a doorknob is about 1 meter.

Scientists use other units to measure distances much smaller or much larger than a meter. For example, the width of the spider shown in **Figure 2** can be measured in centimeters (cm). The prefix *centi-* means "one hundredth." A centimeter is one hundredth of a meter, so there are 100 centimeters in a meter. For lengths smaller than a centimeter, the millimeter (mm) is used. The prefix *milli-* means "one thousandth," so there are 1,000 millimeters in a meter. Distances much longer than a meter can be measured in kilometers (km). The prefix *kilo-* means "one thousand," so there are 1,000 meters in a kilometer. A straight line between San Francisco and Boston would measure about 4,300 kilometers.

FIGURE 2

Measuring Distance

The unit of length that you use to measure distance depends on the size of the distance.

Answer the following questions.

1. **Review** Fill in the following common conversions for length.

   1 m = ______________ mm

   1 m = ______________ cm

   1 km = ______________ m

2. **Measure** What is the distance in centimeters from points A to B on the spider? ________

3. **CHALLENGE** How many of these spiders would fi t side by side in the length of 1 meter?

   ____

   ____

Lab zone Do the Quick Lab *Identifying Motion.*

Assess Your Understanding

1a. Review A ______________________ is a place or object used for comparison to determine if something is in motion.

b. Explain Why is it important to know if your reference point is moving?

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got it?

○ **I get it!** Now I know that an object is in motion if ______________________

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○ I need extra help with ______________________

Go to **MY SCIENCE COACH** *online for help with this subject.*

LESSON
2 Speed and Velocity

UNLOCK THE BIG ?

- How Do You Calculate Speed?
- How Do You Describe Velocity?
- How Do You Graph Motion?

my planet Diary

BLOG

Posted by: Mallory

Location: Fountain Valley, California

Once my sister talked me into going to the roller-skating rink with her. I hate skating, but against my better judgment, I agreed to go. I can skate, but I don't go very fast. At the rink, there were these speed skaters, or, as I like to call them, "assassin skaters." The assassin skaters went ridiculously fast. They were probably going approximately 20 miles per hour in the same direction as me. They zipped past me, just barely missing me.

The worst part about going skating was getting stuck behind a group of skaters or a couple. They went so slowly that you had to speed up to get around them.

Communicate Answer the questions. Discuss your answers with a partner.

1. Do all the skaters in the rink move at the same speed? Explain.

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____

2. Describe a sport or activity in which speed is important.

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PLANET DIARY Go to **Planet Diary** to learn more about speed and velocity.

Lab zone® Do the Inquiry Warm-Up *How Fast and How Far?*

Vocabulary
- speed
- average speed
- instantaneous speed
- velocity
- slope

Skills
- Reading: Identify Supporting Evidence
- Inquiry: Calculate

How Do You Calculate Speed?

You might describe the motion of an airplane as fast or the motion of a snail as slow. By using these words, you are describing the object's speed. The **speed** of an object is the distance the object moves per unit of time. Speed is a type of rate. A rate tells you the amount of something that occurs or changes in one unit of time.

The Speed Equation

To calculate the speed of an object, divide the distance the object travels by the amount of time it takes to travel that distance. This relationship can be written as an equation.

$$\text{Speed} \quad \frac{\text{Distance}}{\text{Time}}$$

The speed equation contains a unit of distance divided by a unit of time. If you measure distance in meters and time in seconds, the SI unit for speed is meters per second, or m/s. (The slash is read as "per.") For example, at its cruising altitude, an airplane might travel at a constant speed of 260 m/s. This means that the airplane will travel a distance of 260 meters in 1 second. The speed of a snail is about 1 mm/s. This means that the snail will travel a distance of 1 millimeter in 1 second. The speed of the airplane is much greater than the speed of the snail because the airplane travels much farther than the snail in the same amount of time.

Vocabulary High-Use Academic Words Complete the following sentence. The relationship between speed, distance, and time can be written as a(n)

____

apply it!

The cyclist shown in the diagram is moving at a constant speed of 10 m/s during her ride.

1. **Identify** Draw arrows on the scale to mark how far the cyclist travels after 1, 2, 3, 3.5, and 4 seconds.
2. **CHALLENGE** How long will it take the cyclist to travel 400 meters?

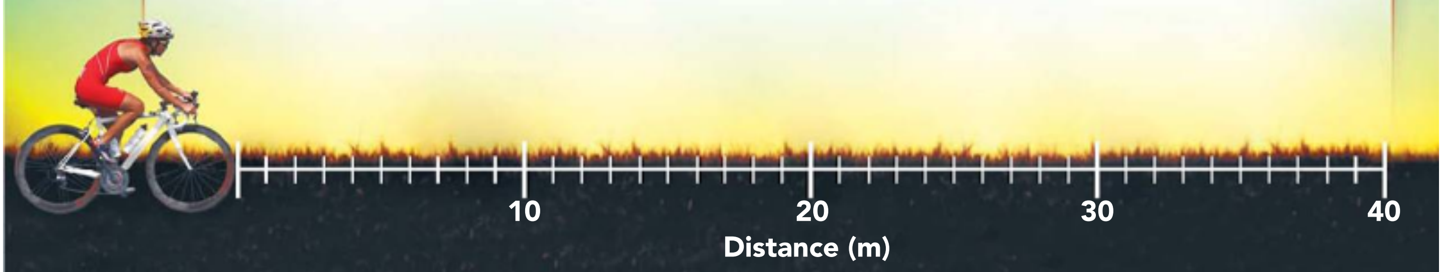


FIGURE 1

Average Speed

Triathletes A and B are competing in a triathlon. The first two legs of the race are swimming and biking.

Calculate **Use the data in the boxes below to calculate each triathlete's average speed during the swimming and biking legs of the race.**

Average Speed

When a plane is at its cruising altitude, it can travel at a constant speed for many hours. But the speed of most moving objects is not constant. In a race known as the triathlon, the competitors (or triathletes) first swim, then bike, and finally run. The speeds of the triathletes change throughout the race. They travel slowest when they swim, a little faster when they run, and fastest when they bike.

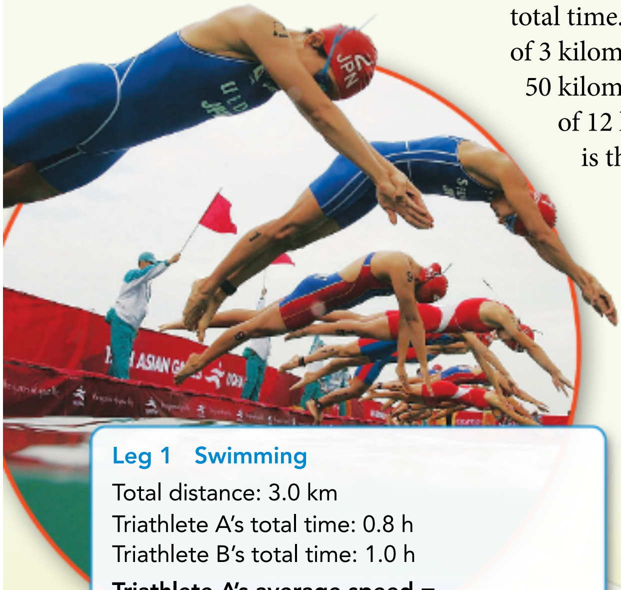
Although the triathletes do not travel at a constant speed, they do have an average speed throughout the race. To calculate average speed, divide the total distance traveled by the total time. For example, suppose a triathlete swims a distance of 3 kilometers in 1 hour. Then the triathlete bikes a distance of 50 kilometers in 3 hours. Finally, the triathlete runs a distance of 12 kilometers in 1 hour. The average speed of the triathlete is the total distance divided by the total time.

$$\text{Total distance} = 3\text{ km} + 50\text{ km} + 12\text{ km} = 65\text{ km}$$

$$\text{Total time} = 1\text{ h} + 3\text{ h} + 1\text{ h} = 5\text{ h}$$

$$\text{Average speed} = \frac{65\text{ km}}{5\text{h}} = 13\text{ km/h}$$

The triathlete's average speed is 13 kilometers per hour.



Leg 1 Swimming

Total distance: 3.0 km

Triathlete A's total time: 0.8 h

Triathlete B's total time: 1.0 h

Triathlete A's average speed =

Triathlete B's average speed =

Leg 2 Biking

Total distance: 50.0 km

Triathlete A's total time: 3.0 h

Triathlete B's total time: 2.5 h

Triathlete A's average speed =

Triathlete B's average speed =

Instantaneous Speed

Instantaneous Speed Suppose Triathlete B passes Triathlete A during the biking leg. At that moment, Triathlete B has a greater instantaneous speed than Triathlete A. Instantaneous speed is the speed at which an object is moving at a given instant in time. It is important not to confuse instantaneous speed with average speed. The triathlete with the greatest average speed, not the greatest instantaneous speed, wins the race.

apply it!

The triathletes run in the third and final leg of the triathlon.

Leg 3 *Running*
Total distance: 12.0 km
Triathlete A's total time: 1.2 h
Triathlete B's total time: 1.0 h

1 **Calculate** Use the data from all three legs to solve for each triathlete's average speed.

Total distance =	
Triathlete A's total time =	
Triathlete A's average speed =	
Triathlete B's total time =	
Triathlete B's average speed =	

2 **Identify** Which triathlete finishes first? ____________

Lab zone Do the Lab Investigation *Stopping on a Dime.*

Assess Your Understanding

1a. Identify The (instantaneous/average) speed is the speed of the object at a given instant in time. The (instantaneous/average) speed is the speed of the object over a longer period of time.

b. Apply Concepts The speedometer in a car gives the car's ____________ speed.

got it?

O **I get it!** Now I know to calculate the speed of an object, I need to ____________

____

O I need extra help with ____________

Go to **MY SCIENCE COACH** *online for help with this subject.*

How Do You Describe Velocity?

Knowing the speed at which something travels does not tell you everything about its motion. To describe an object's motion, you also need to know its direction. For example, suppose you hear that a thunderstorm is traveling at a speed of 25 km/h. Should you prepare for the storm? That depends on the direction of the storm's motion. Because storms usually travel from west to east in the United States, you probably need not worry if you live west of the storm. You probably should take cover if you live east of the storm.

When you know both the speed and direction of an object's motion, you know the velocity of the object. Speed in a given direction is called **velocity.** You know the velocity of the storm when you know that it is moving 25 km/h eastward.

At times, describing the velocity of moving objects can be very important. For example, air traffic controllers must keep close track of the velocities of the aircraft under their control. These velocities change as airplanes move overhead and on the runways. An error in determining a velocity, either in speed or in direction, could lead to a collision.

Velocity is also important to airplane pilots. For example, the stunt pilots in **Figure 2** make spectacular use of their control over the velocity of their aircraft. Stunt pilots use this control to stay in close formation while flying graceful maneuvers at high speeds.

Identify Supporting Evidence Underline the reason why velocity is important to air traffi c controllers.

FIGURE 2

Velocity

These stunt pilots are perform-ing at an air show.

Explain **Why is velocity and not just speed important to these pilots?**

Table of Contents

How Do You Graph Motion?

The graphs you see in **Figure 4** and **Figure 5** are distance-versus-time motion graphs. **You can show the motion of an object on a line graph in which you plot distance versus time.** By tradition, time is shown on the horizontal axis, or *x*-axis. Distance is shown on the vertical axis, or *y*-axis. A point on the line represents the distance an object has traveled during a particular time. The *x* value of the point is time, and the *y* value is distance.

The steepness of a line on a graph is called **slope.** The slope tells you how fast one variable changes in relation to the other variable in the graph. In other words, slope tells you the rate of change. Since speed is the rate that distance changes in relation to time, the slope of a distance-versus-time graph represents speed. The steeper the slope is, the greater the speed. A constant slope represents motion at constant speed.

FIGURE 4

INTERACTIVE ART **Constant Speed**

The graph shows the motion of a jogger.

Use the graph to answer the questions.

1. **Read Graphs** What is the jogger's speed?

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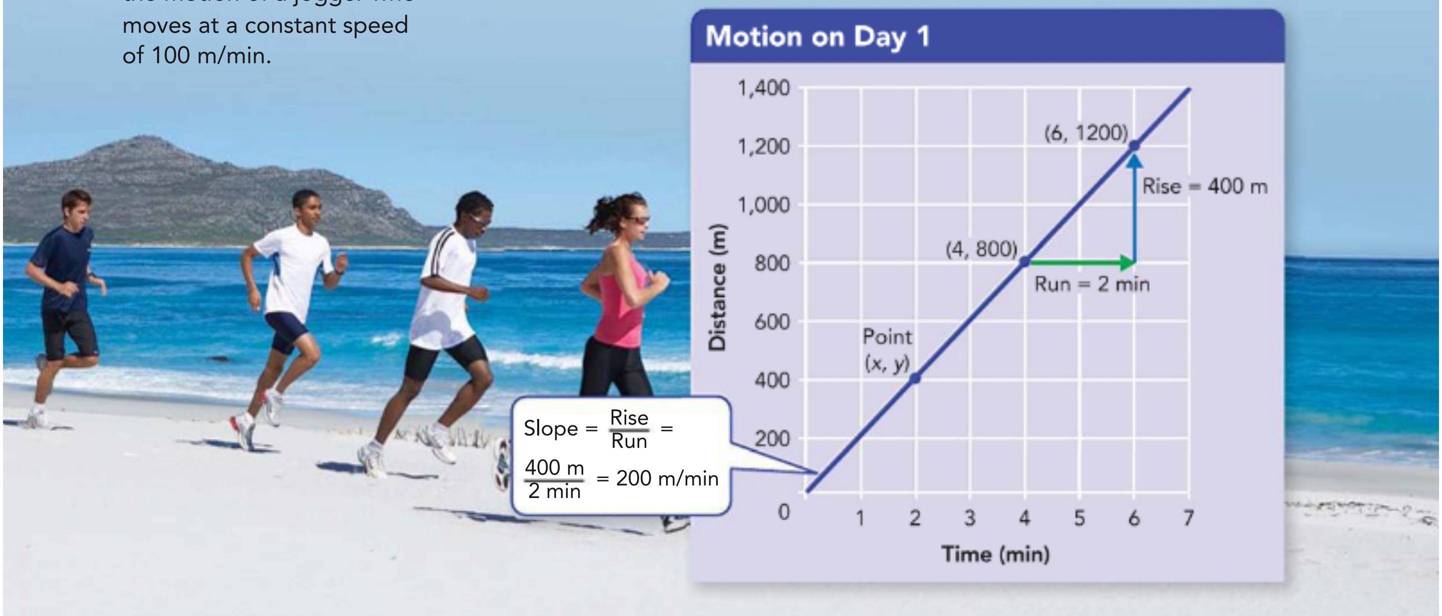
2. **Predict** On the same graph, draw a line that represents the motion of a jogger who moves at a constant speed of 100 m/min.

Calculating Slope

You can calculate the slope of a line by dividing the rise by the run. The rise is the vertical difference between any two points on the line. The run is the horizontal difference between the same two points.

$$\text{Slope} \quad \frac{\text{Rise}}{\text{Run}}$$

In **Figure 4,** using the points shown, the rise is 400 meters and the run is 2 minutes. To find the slope, you divide 400 meters by 2 minutes. The slope is 200 meters per minute.



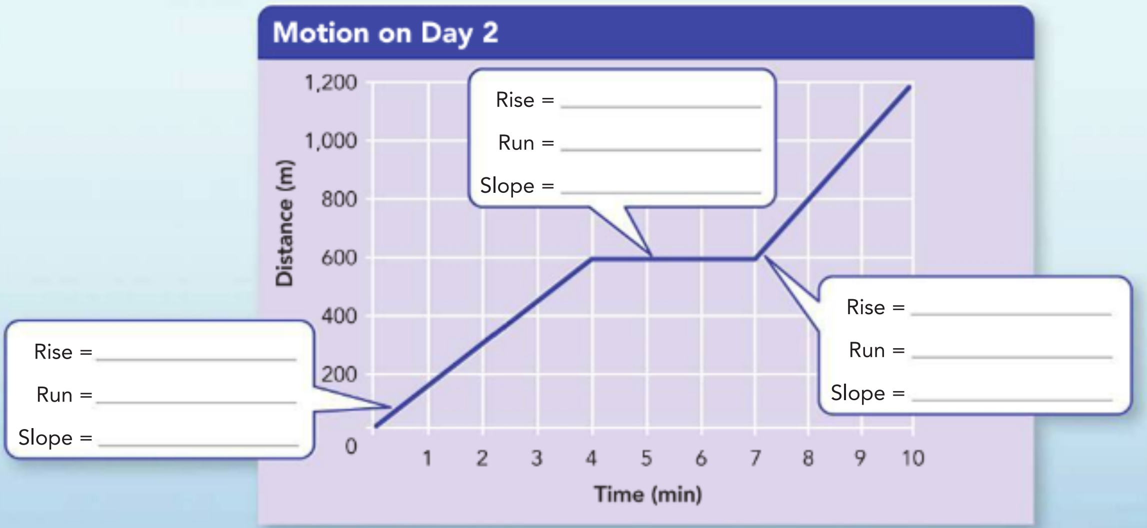
Different Slopes Most moving objects do not travel at a constant speed. For example, the graph in **Figure 5** shows a jogger's motion on the second day of training. The line is divided into three segments. The slope of each segment is different. From the steepness of the slopes you can tell that the jogger ran fastest during the third segment. The horizontal line in the second segment shows that the jogger's distance did not change at all. The jogger was resting during the second segment.

FIGURE 5

Changing Speed

The graph shows how the speed of a jogger varies during her second day of training.

Read Graphs **Find the rise, the run, and the slope for each segment of the graph. Write the answers in the boxes below.**



Lab zone Do the Quick Lab *Motion Graphs.*

Assess Your Understanding

3a. Identify The ____________ of a distance-versus-time graph shows you the speed of a moving object.

b. Calculate The rise of a line on a distance-versus-time graph is 900 m and the run is 3 min. What is the slope of the line?

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c. Apply Concepts Is it possible for a distance-versus-time graph to be a vertical line? Explain.

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got it?

○ **I get it!** Now I know to show the motion of an object on a line graph, you ____________________

____

○ I need extra help with ____________________

Go to my science COACH *online for help with this subject.*

LESSON 3

Acceleration

What Is Acceleration?

How Do You Graph Acceleration?

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FUN FACT

Jumping Spider

A small spider, less than 2 centimeters long, spots an insect. The spider crouches and crawls forward. Then it lifts its front legs and leaps, landing right on its victim!

Amazingly, a jumping spider can jump 10 to 40 times its body length. To capture prey from that far away, it must accurately estimate its initial velocity. Once the spider jumps, the force of gravity controls its motion, causing it to follow a curved path. Its velocity changes at every point along the path until it lands on its prey.

Write your answer to the question below.

Think of a sport or activity in which the goal is to hit a target from far away. What are some of the challenges?

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____

____

PLANET DIARY Go to **Planet Diary** to learn more about acceleration.

Lab zone Do the Inquiry Warm-Up *Will You Hurry Up?*

What Is Acceleration?

Suppose you are a passenger in a car stopped at a red light. When the light changes to green, the driver steps on the accelerator. As a result, the car speeds up, or accelerates. In everyday language, acceleration means "the process of speeding up."

Acceleration has a more precise definition in science. Scientists define **acceleration** as the rate at which velocity changes. Recall that velocity describes both the speed and direction of an object. A change in velocity can involve a change in either speed or direction—or both. **In science, acceleration refers to increasing speed, decreasing speed, or changing direction.**

Vocabulary
- acceleration

Skills
- Reading: Identify the Main Idea
- Inquiry: Graph

Changing Speed Whenever an object's speed changes, the object accelerates. A car that begins to move from a stopped position or speeds up to pass another car is accelerating. People can accelerate too. For example, you accelerate when you coast down a hill on your bike.

Just as objects can speed up, they can also slow down. This change in speed is sometimes called deceleration, or negative acceleration. A car decelerates as it comes to a stop at a red light. A water skier decelerates as the boat slows down.

Identify the Main Idea Underline the main idea in the section called Changing Speed.

Changing Direction Even an object that is traveling at a constant speed can be accelerating. Recall that acceleration can be a change in direction as well as a change in speed. Therefore, a car accelerates as it follows a gentle curve in the road or changes lanes. Runners accelerate as they round the curve in a track. A softball accelerates when it changes direction as it is hit.

Many objects continuously change direction without changing speed. The simplest example of this type of motion is circular motion, or motion along a circular path. For example, the seats on a Ferris wheel accelerate because they move in a circle.

FIGURE 1
Acceleration
During the game of soccer, a soccer ball can show three types of acceleration—increasing speed, decreasing speed, and changing direction.

Interpret Photos Label the type of acceleration that is occurring in each of the photos.

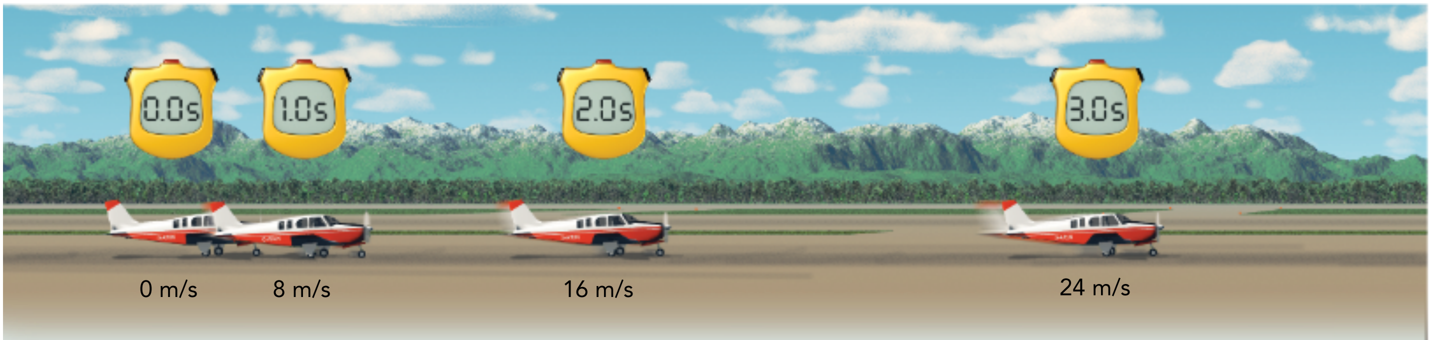

FIGURE 2
Acceleration
The airplane is accelerating at a rate of 8 m/s^2.

Predict **Determine the speed of the airplane at 4.0 s and 5.0 s. Write your answers in the boxes next to each airplane.**

Calculating Acceleration

Acceleration describes the rate at which velocity changes. If an object is not changing direction, you can describe its acceleration as the rate at which its speed changes. To determine the acceleration of an object moving in a straight line, you calculate the change in speed per unit of time. This is summarized by the following equation.

$$\text{Acceleration} = \frac{\text{Final Speed} - \text{Initial Speed}}{\text{Time}}$$

If speed is measured in meters per second (m/s) and time is measured in seconds, the SI unit of acceleration is meters per second per second, or m/s^2. Suppose speed is measured in kilometers per hour and time is measured in hours. Then the unit for acceleration is kilometers per hour per hour, or km/h^2 .

To understand acceleration, imagine a small airplane moving down a runway. **Figure 2** shows the airplane's speed after each second of the first three seconds of its acceleration. To calculate the acceleration of the airplane, you must first subtract the initial speed of 0 m/s from its final speed of 24 m/s. Then divide the change in speed by the time, 3 seconds.

$$\text{Acceleration} = \frac{24\text{ m/s} - 0\text{ m/s}}{3\text{s}}$$

$$\text{Acceleration} = 8\text{ m/s}^2$$

The airplane accelerates at a rate of 8 m/s^2. This means that the airplane's speed increases by 8 m/s every second. Notice in **Figure 2** that after each second of travel, the airplane's speed is 8 m/s greater than its speed in the previous second.

FIGURE 3
Deceleration
An airplane touches down on the runway with a speed of 70 m/s. It decelerates at a rate of –5 m/s^2 .

Predict **Determine the speed of the airplane after each second of its deceleration. Write your answers in the table to the right.**

Time (s)	1	2	3	4
Speed (m/s)				

do the math!

Large accelerations are part of the thrill in many amusement park rides. The problems below are based on actual amusement park rides.

1 **Calculate** One type of ride falls straight down for 3 seconds. During this time, the ride accelerates from a speed of 0 m/s to a speed of 30 m/s. What is the average acceleration of the ride?

Initial speed = ________ Final speed = __________ Time = ________
Average acceleration =

2 **Calculate** A roller coaster accelerates from a speed of 4 m/s to 22 m/s in 3 seconds. What is the average acceleration of the ride?

Initial speed = _________ Final speed = __________ Time = ________
Average acceleration =

Lab zone Do the Quick Lab *Describing Acceleration.*

Assess Your Understanding

1a. Define The rate at which velocity changes is called ____________________

b. Infer A softball has a (positive/negative) acceleration when it is thrown. A softball has a (positive/negative) acceleration when it is caught.

c. Explain A girl skates around the perimeter of a circular ice rink at a constant speed of 2 m/s. Is the girl accelerating? Explain.

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got it?

O **I get it!** Now I know that in science acceleration refers to ____________________

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O I need extra help with ____________________

Go to **MY SCIENCE COACH** *online for help with this subject.*

How Do You Graph Acceleration?

Suppose you bike down a long, steep hill. At the top of the hill, your speed is 0 m/s. As you start down the hill, your speed increases. Each second, you move at a greater speed and travel a greater distance than the second before. During the five seconds it takes you to reach the bottom of the hill, you are an accelerating object. **You can use both a speed-versus-time graph and a distance-versus-time graph to analyze the motion of an accelerating object.**

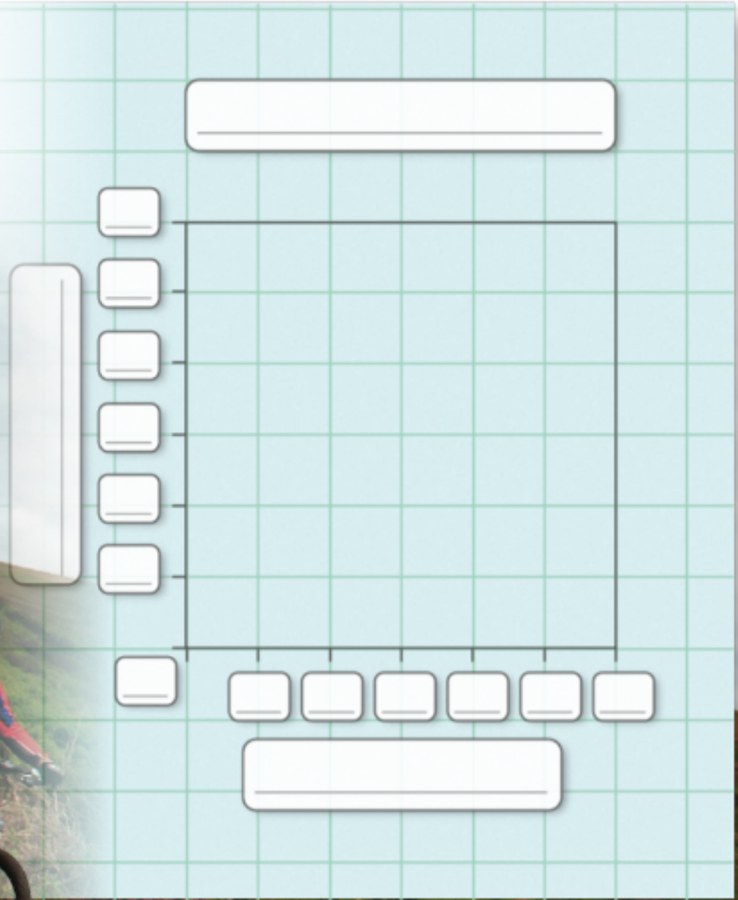
FIGURE 4

VIRTUAL LAB **Speed-Versus-Time Graph**

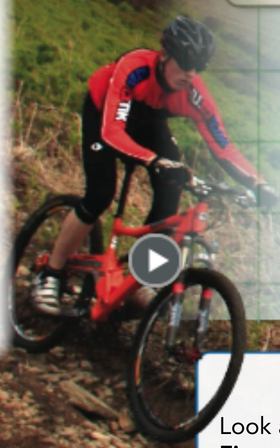
The data in the table show how your speed changes during each second of your bike ride.

Use the data to answer the questions.

Time (s)	Speed (m/s)
0	0
1	2
2	4
3	6
4	8
5	10



1. **Graph** Use this data to plot a line graph. Plot time on the horizontal axis. Plot speed on the vertical axis. Give the graph a title.
2. **Calculate** What is the slope of the graph?



Analyzing a Speed-Versus-Time Graph

Look at the speed-versus-time graph that you made in **Figure 4.** What can you learn about your motion by analyzing this graph? First, since the line slants upward, the graph shows that your speed was increasing. Next, since the line is straight, you can tell that your acceleration was constant. A slanted, straight line on a speed-versus-time graph means that the object is accelerating at a constant rate. Your acceleration is the slope of the line.

FIGURE 5

▶ INTERACTIVE ART Distance-Versus-Time Graph

The data in the table show how your distance changes during each second of your bike ride.

Use the data to answer the questions.

Time (s)	Distance (m)
0	0
1	1
2	4
3	9
4	16
5	25

1. Graph Use this data to create a line graph. Plot time on the horizontal axis. Plot distance on the vertical axis. Give the graph a title.
2. CHALLENGE How does the distance change with time?

____

____

____

____

Analyzing a Distance-Versus-Time Graph

Look at the distance-versus-time graph that you made in **Figure 5.** The curved line tells you that during each second, you traveled a greater distance than the second before. For example, you traveled a greater distance during the third second than you did during the first second.

The curved line in **Figure 5** also tells you that during each second your speed was greater than the second before. Recall that the slope of a distance-versus-time graph is the speed of an object. From second to second, the slope of the line in **Figure 5** gets steeper. Since the slope is increasing, you can conclude that your speed was also increasing. You were accelerating.

Lab zone Do the Quick Lab *Graphing Acceleration.*

Assess Your Understanding

got it?

○ **I get it!** Now I know that the two types of graphs that you can use to analyze the motion of an accelerating object are ______________________

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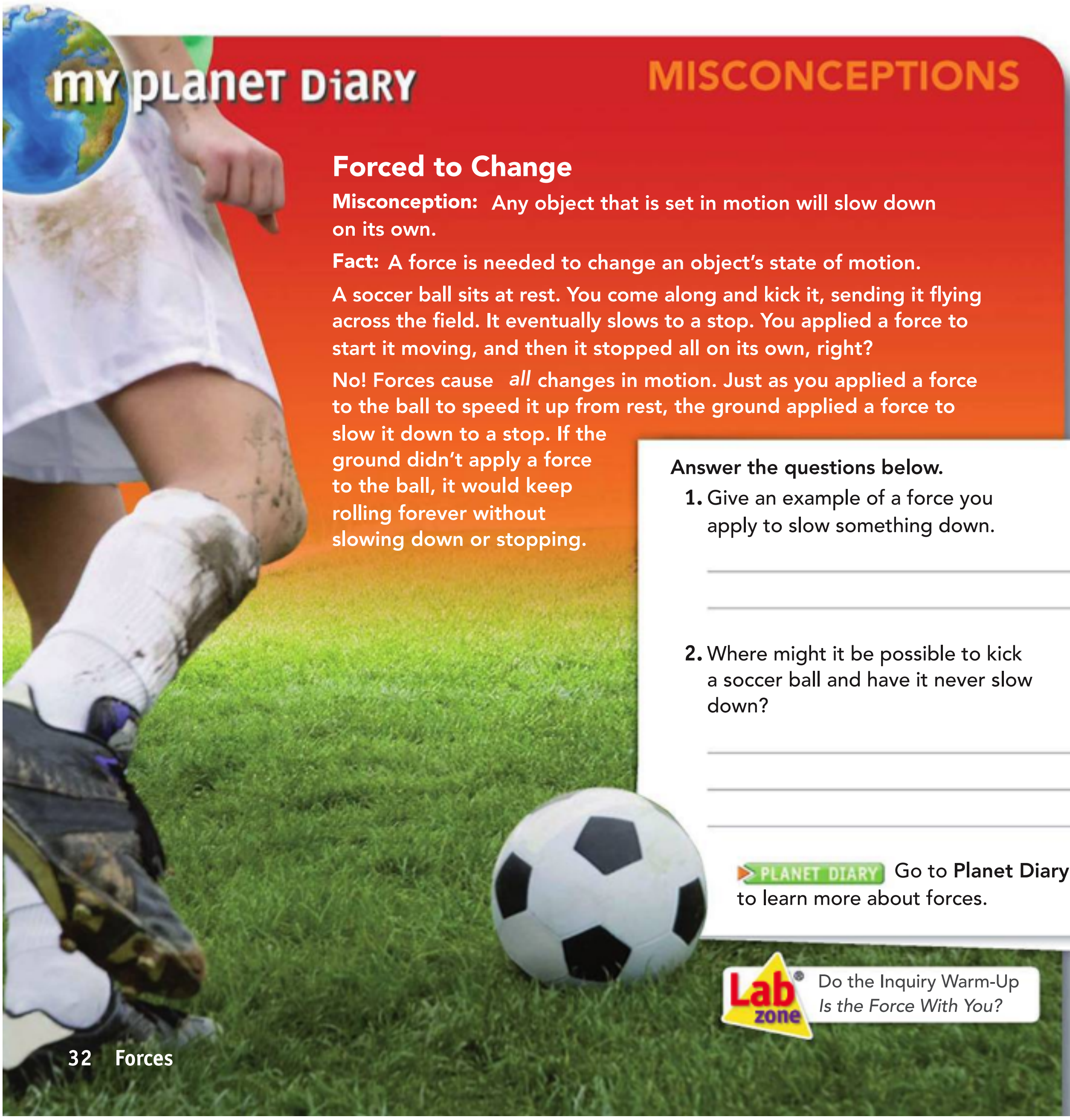
○ I need extra help with ______________________

Go to my science coach *online for help with this subject.*

LESSON 1

The Nature of Force

- How Are Forces Described?
- How Do Forces Affect Motion?



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MISCONCEPTIONS

Forced to Change

Misconception: Any object that is set in motion will slow down on its own.

Fact: A force is needed to change an object's state of motion.

A soccer ball sits at rest. You come along and kick it, sending it flying across the field. It eventually slows to a stop. You applied a force to start it moving, and then it stopped all on its own, right?

No! Forces cause *all* changes in motion. Just as you applied a force to the ball to speed it up from rest, the ground applied a force to slow it down to a stop. If the ground didn't apply a force to the ball, it would keep rolling forever without slowing down or stopping.

Answer the questions below.

1. Give an example of a force you apply to slow something down.

____

____

2. Where might it be possible to kick a soccer ball and have it never slow down?

____

____

____

PLANET DIARY Go to **Planet Diary** to learn more about forces.

Lab zone Do the Inquiry Warm-Up *Is the Force With You?*

Vocabulary
- force
- newton
- net force

Skills
- Reading: Relate Text and Visuals
- Inquiry: Make Models

How Are Forces Described?

In science, the word *force* has a simple and specific meaning. A **force** is a push or a pull. When one object pushes or pulls another object, the first object exerts a force on the second object. You exert a force on a computer key when you push it. You exert a force on a chair when you pull it away from a table.

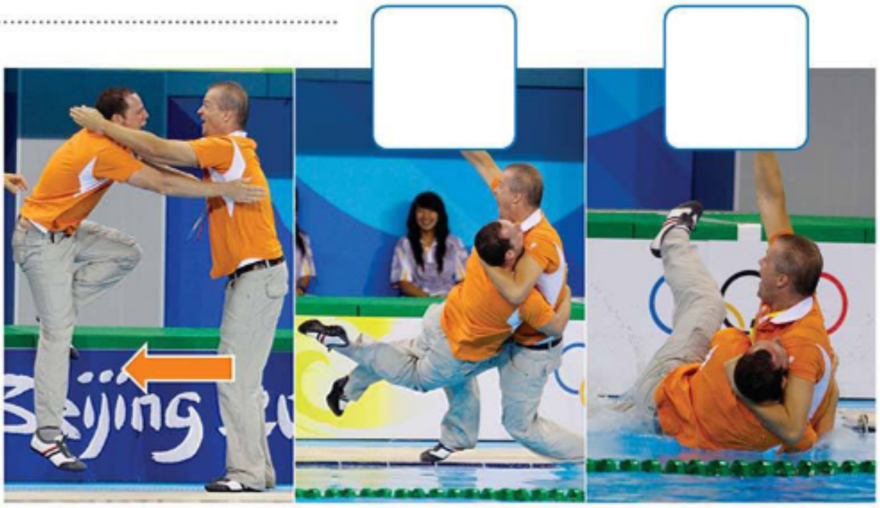
Like velocity and acceleration, a force is described by its strength and by the direction in which it acts. Pushing to the left is a different force from pushing to the right. The direction and strength of a force can be represented by an arrow. The arrow points in the direction of the force, as shown in **Figure 1.** The length of the arrow tells you the strength of the force—the longer the arrow, the greater the force. The strength of a force is measured in the SI unit called the **newton** (N), after scientist Sir Isaac Newton.

FIGURE 1

Describing Forces

Forces act on you whenever your motion changes. In the photos at the right, two men are celebrating an Olympic victory. Forces cause them to pull each other in for a hug, lean over, and fall into the pool.

Identify In the box within each photo, draw an arrow that represents the force acting on the person on the right. The fi rst one is done as an example.



Lab zone — Do the Quick Lab *What Is Force?*

Assess Your Understanding

got it?

- O **I get it!** Now I know that forces are described by ______________________
- O I need extra help with ______________________

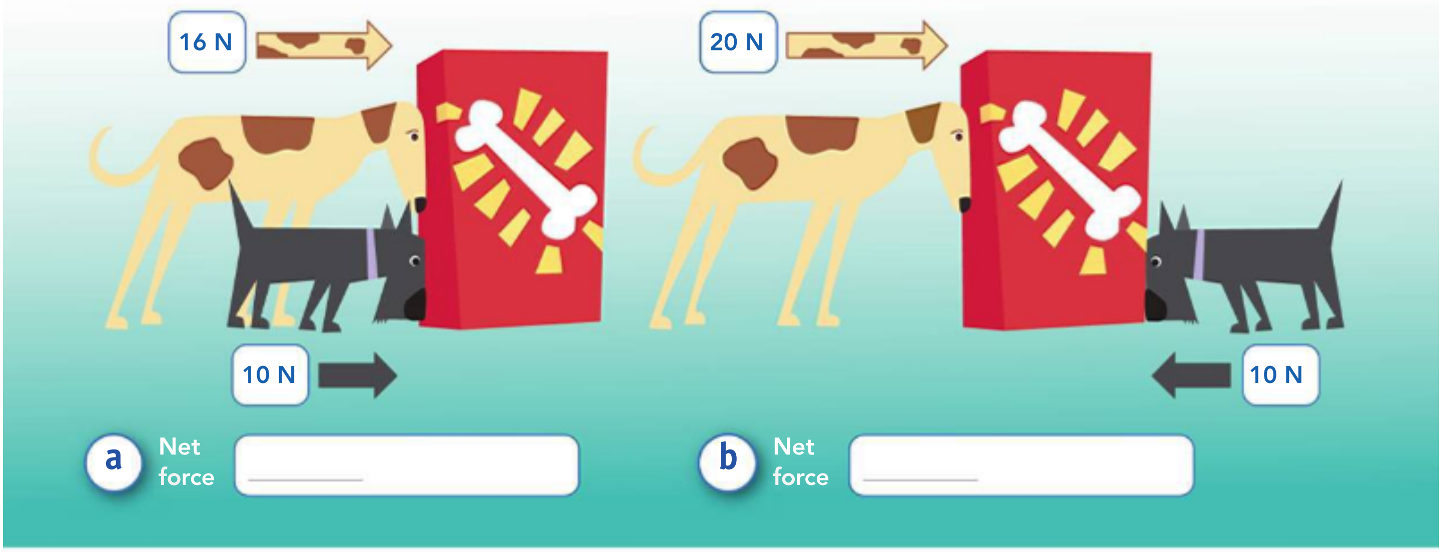
Go to my science coach *online for help with this subject.*

FIGURE 2

INTERACTIVE ART **Net Force**

The change in motion of an object is determined by the net force acting on the object.

Make Models **Calculate and draw an arrow for the net force for each situation in the boxes below.**



How Do Forces Affect Motion?

Often more than one force acts on an object at the same time. The combination of all the forces on an object is called the **net force.** The net force determines if and how an object will accelerate.

You can find the net force on an object by adding together the strengths of all the individual forces acting on the object. Look at **Figure 2a.** The big dog pushes on the box with a force of 16 N to the right. The small dog pushes on the box with a force of 10 N to the right. The net force on the box is the sum of these forces. The box will accelerate to the right. In this situation, there is a nonzero net force. **A nonzero net force causes a change in the object's motion.**

What if the forces on an object aren't acting in the same direction? In **Figure 2b,** the big dog pushes with a force of 20 N. The small dog still pushes with a force of 10 N, but now they're pushing against each other. When forces on an object act in opposite directions, the strength of the net force is found by subtracting the strength of the smaller force from the strength of the larger force. You can still think of this as *adding* the forces together if you think of all forces that act to the right as positive forces and all forces that act to the left as negative forces. The box will accelerate to the right. When forces act in opposite directions, the net force is in the same direction as the larger force.

Relate Text and Visuals Use the information in the text to determine the net force of these two force arrows.

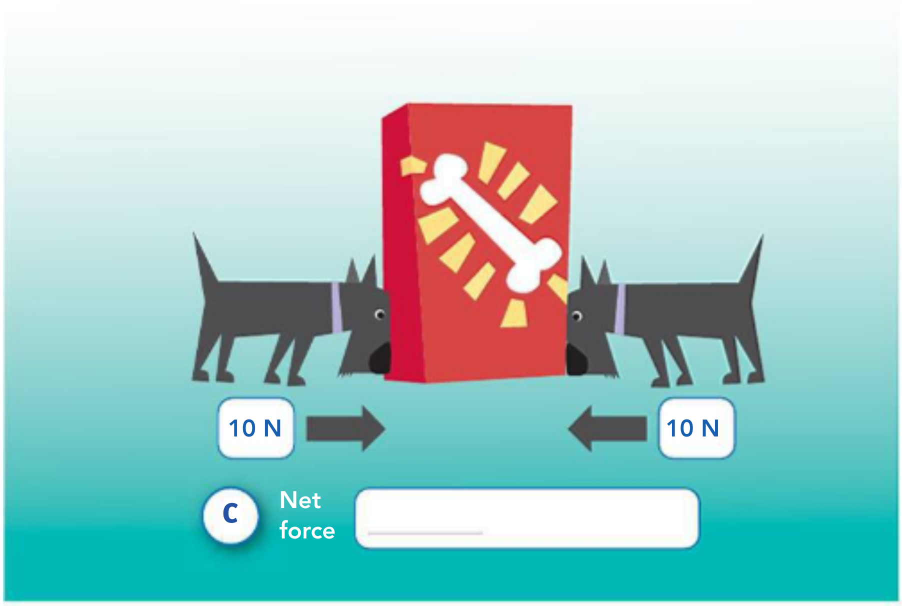
3 N → 5 N →

Circle the net force below.

→ 8 N

← 2 N

← 8 N



Use what you know about net force to describe the motion of the box in **Figure 2c.** Assume that the box starts at rest.

____

____

____

____

apply it!

1 You pull on your dog's leash to the right with a 12 N force. Your dog pulls to the left with a 6 N force. Sketch this situation, including labeled force arrows, below.

2 What is the net force on the leash? Calculate it. Draw and label it in the space above.

____

Lab zone — Do the Quick Lab *Modeling Unbalanced Forces.*

Assess Your Understanding

1a. **Calculate** You push on a desk with a force of 120 N to the right. Your friend pushes on the same desk with a force of 90 N to the left. What is the net force on the desk?

____

b. **Predict** Your friend increases her force on the desk by 30 N. She doesn't change the direction of her push. What happens to the net force on the desk? Will the desk accelerate?

____

____

got it?

O **I get it!** Now I know that changes in motion are caused by ______________________________

____

O I need extra help with ______________________________

Go to MY SCIENCE COACH *online for help with this subject.*

LESSON 2

Friction and Gravity

UNLOCK THE BIG ?

- What Factors Affect Friction?
- What Factors Affect Gravity?

my planet Diary

CAREERS

Space Athletes

Have you ever seen pictures of astronauts playing golf on the moon or playing catch in a space station? Golf balls and baseballs can float or fly farther in space, where gravitational forces are weaker than they are on Earth. Imagine what professional sports would be like in reduced gravity!

You may not have to imagine much longer. At least one company specializes in airplane flights that simulate a reduced gravity environment. Similar to NASA training flights that astronauts use when preparing to go into space, these flights allow passengers to fly around the cabin. In environments with reduced gravity, athletes can perform jumps and stunts that would be impossible on Earth. As technology improves, permanent stadiums could be built in space for a whole new generation of athletes.

Communicate **Discuss these questions with a partner and then answer them below.**

1. Sports can be more fun in reduced gravity. What jobs could be harder or less fun to do in space? Why?

____

____

____

2. What kinds of sports do you think could be more fun in space? Why?

____

____

____

PLANET DIARY Go to **Planet Diary** to learn more about everyday forces.

Lab zone® Do the Inquiry Warm-Up *Observing Friction.*

Vocabulary

- friction
- sliding friction
- static friction
- fluid friction
- rolling friction
- gravity
- mass
- weight

Skills

- Reading: Identify Supporting Evidence
- Inquiry: Design Experiments

What Factors Affect Friction?

If you slide a book across a table, the surface of the book rubs against the surface of the table. The force that two surfaces exert on each other when they rub against each other is called **friction**.

Two factors that affect the force of friction are the types of surfaces involved and how hard the surfaces are pushed together. The football player in **Figure 1** is pushing on a blocking sled. If his coach wanted to make it harder to move the sled, the coach could change the surface of the sled. Covering the bottom of the sled with rubber would increase friction and make the sled harder to move. In general, smooth surfaces produce less friction than rough surfaces.

What would happen if the football player switched to a much heavier sled? He would find the heavier sled harder to push because it pushes down harder against the ground. Similarly, if you rubbed your hands together forcefully, there would be more friction than if you rubbed your hands together lightly. Friction increases when surfaces push harder against each other.

Friction acts in a direction opposite to the direction of the object's motion. Without friction, a moving object will not stop until it strikes another object.

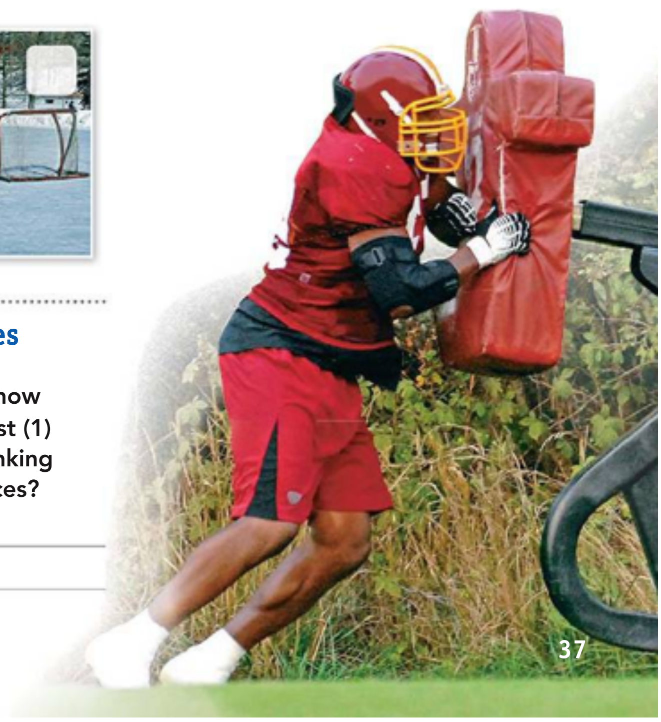
Vocabulary Latin Word Origins *Friction* comes from the Latin word *fricare*. Based on the definition of friction, what do you think *fricare* means?

- ○ to burn
- ○ to rub
- ○ to melt

FIGURE 1

ART IN MOTION **Friction and Different Surfaces**

involved. **Sequence** Rank the surfaces above by how hard it would be to push a sled over them, from easiest (1) to hardest (3). (Each surface is fl at.) What does this ranking tell you about the amount of friction over these surfaces?



Sliding Friction

Sliding friction occurs when two solid surfaces slide over each other. Sliding friction is what makes moving objects slow down and stop. Without sliding friction, a penguin that slid down a hill wouldn't stop until he hit a wall!

Classify **Label five examples of sliding friction and compare with a classmate.**

Friction acts opposite the direction of motion.

Direction of motion

Friction

Static Friction

Static friction acts between objects that aren't moving. Think about trying to push a couch across the room. If you don't push hard enough, it won't move. The force that's keeping you from moving it is static friction. Once you push hard enough to overcome static friction, the couch starts moving and there is no more static friction. However, there is sliding friction.

Classify **Label five examples of static friction and compare with a classmate.**

Draw an arrow representing the frictional force at work.

Fluid Friction

Fluids, such as water and air, are materials that flow easily. **Fluid friction** occurs when a solid object moves through a fluid. Fluid friction is easier to overcome than sliding friction. This is why sidewalks become slippery when they get wet.

Classify **Label five examples of fluid friction and compare with a classmate.**

Draw an arrow representing the frictional force at work.

Rolling Friction

When an object rolls across a surface, rolling friction occurs. Rolling friction is much easier to overcome than sliding friction for similar materials. That's why it's easy to push a bike along the sidewalk when the wheels can turn, but much harder to push the bike if you're applying the brakes and the tires slide, not roll.

Classify **Label five examples of rolling friction and compare with a classmate.**

Draw an arrow representing the frictional force at work.

apply it!

Your family is moving and isn't sure how to best overcome friction while moving furniture. You have a spring scale, wood blocks to represent your furniture, and sandpaper, aluminum foil, marbles, and olive oil as possible surfaces to slide your furniture over.

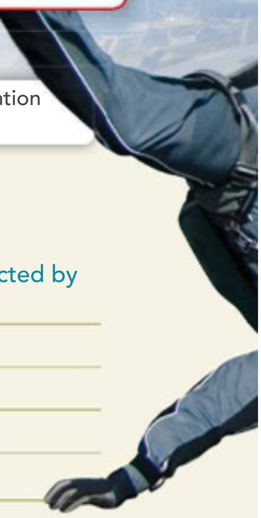
Design Experiments **Design an experiment that will help you determine which material will reduce friction the most.**

You know that friction occurs between surfaces when they slide against each other. If you measure the applied force required to push something across a surface, you know that your applied force would (increase/ decrease) as friction increased.

STEP 1 **Measure** How would you determine your applied force in this experiment?

STEP 2 **Control Variables** What variables would you have to control to keep your results accurate?

STEP 3 **Create Data Tables** Draw the data table you would use when performing this experiment.



Lab zone Do the Lab Investigation *Sticky Sneakers.*

Assess Your Understanding

1a. **List** Name four types of friction and give an example of each.

b. **Classify** What types of friction occur between your bike tries and the ground when you ride over cement, ride through a puddle, and apply your brakes?

got it?

○ **I get it!** Now I know that friction is affected by

○ I need extra help with

Go to **MY SCIENCE COACH** *online for help with this subject.*

What Factors Affect Gravity?

A skydiver would be surprised if she jumped out of a plane and did not fall. We are so used to objects falling that we may not have thought about why they fall. One person who thought about it was Sir Isaac Newton. He concluded that a force acts to pull objects straight down toward the center of Earth. **Gravity** is a force that pulls objects toward each other.

Universal Gravitation

Newton realized that gravity acts everywhere in the universe, not just on Earth. It is the force that makes the skydivers in **Figure 2** fall to the ground. It is the force that keeps the moon orbiting around Earth. It is the force that keeps all the planets in our solar system orbiting around the sun.

What Newton realized is now called the law of universal gravitation. The law of universal gravitation states that the force of gravity acts between all objects in the universe that have mass. This means that any two objects in the universe that have mass attract each other. You are attracted not only to Earth but also to the moon, the other planets in the solar system, and all the objects around you. Earth and the objects around you are attracted to you as well. However, you do not notice the attraction among small objects because these forces are extremely small compared to the force of Earth's attraction.

FIGURE 2

Observing Gravity

Newton published his work on gravity in 1687.

Observe What observations might you make today that would lead you to the same conclusions about gravity? Write down your ideas below.

Factors Affecting Gravity

A gravitational force exists between any two objects in the universe. However, you don't see your pencil fly toward the wall the way you see it fall toward Earth. That's because the gravitational force between some objects is stronger than the force between others. You observe only the effects of the strongest gravitational forces. **Two factors affect the gravitational attraction between objects: mass and distance.** Mass is a measure of the amount of matter in an object. The SI unit of mass is the kilogram.

The more mass an object has, the greater the gravitational force between it and other objects. Earth's gravitational force on nearby objects is strong because the mass of Earth is so large. The more massive planets in **Figure 3** interact with a greater gravitational force than the less massive planets. Gravitational force also depends on the distance between the objects' centers. As distance increases, gravitational force decreases. That's why Earth can exert a visible gravitational force on a pencil in your room and not on a pencil on the moon.

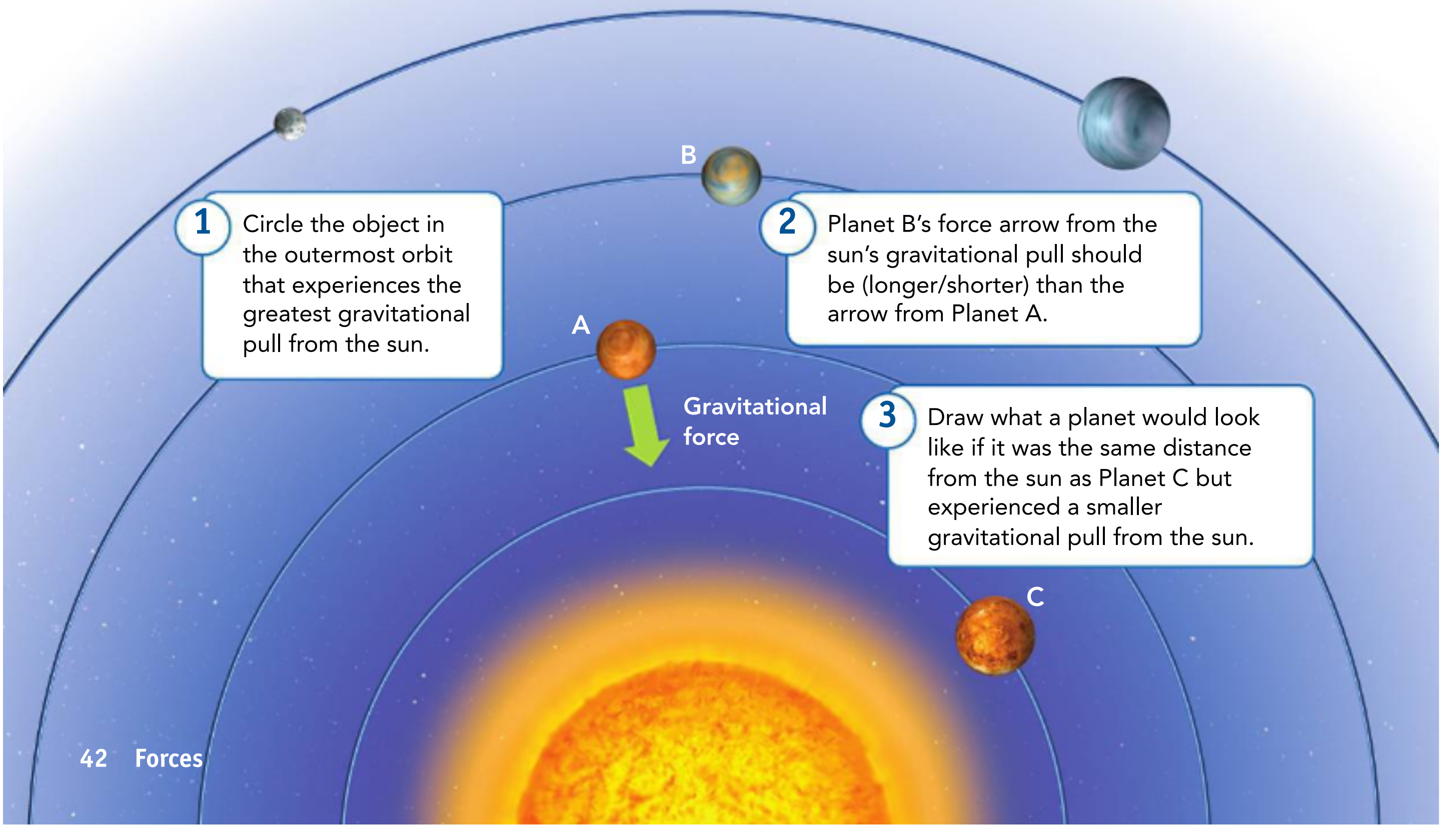
Identify Supporting Evidence Underline the factors that determine how strong the gravitational force is between two objects.

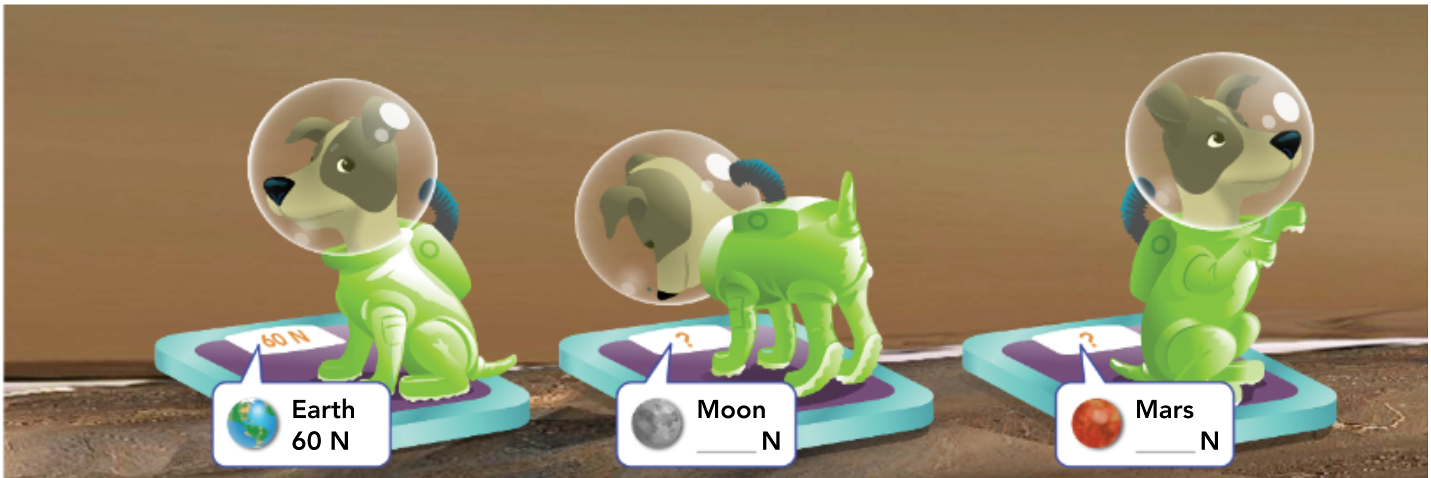
FIGURE 3

Gravitational Attraction

Gravitational attraction depends on two factors: mass and distance. Suppose there was a solar system that looked like this.

Interpret Diagrams Use the diagram below to compare the gravitational force between different planets and their sun. Assume all planets are made of the same material, so bigger planets have more mass.





Weight and Mass

Weight and Mass Mass is sometimes confused with weight. Mass is a measure of the amount of matter in an object. Weight is a measure of the force of gravity on an object. When you stand on a bathroom scale, it displays the gravitational force Earth is exerting on you.

At any given time, your mass is the same on Earth as it would be on any other planet. But weight varies with the strength of the gravitational force. The dog in **Figure 4** has a different weight at different places in the solar system. On the moon, he would weigh about one sixth of what he does on Earth. On Mars, he would weigh just over a third of what he does on Earth.

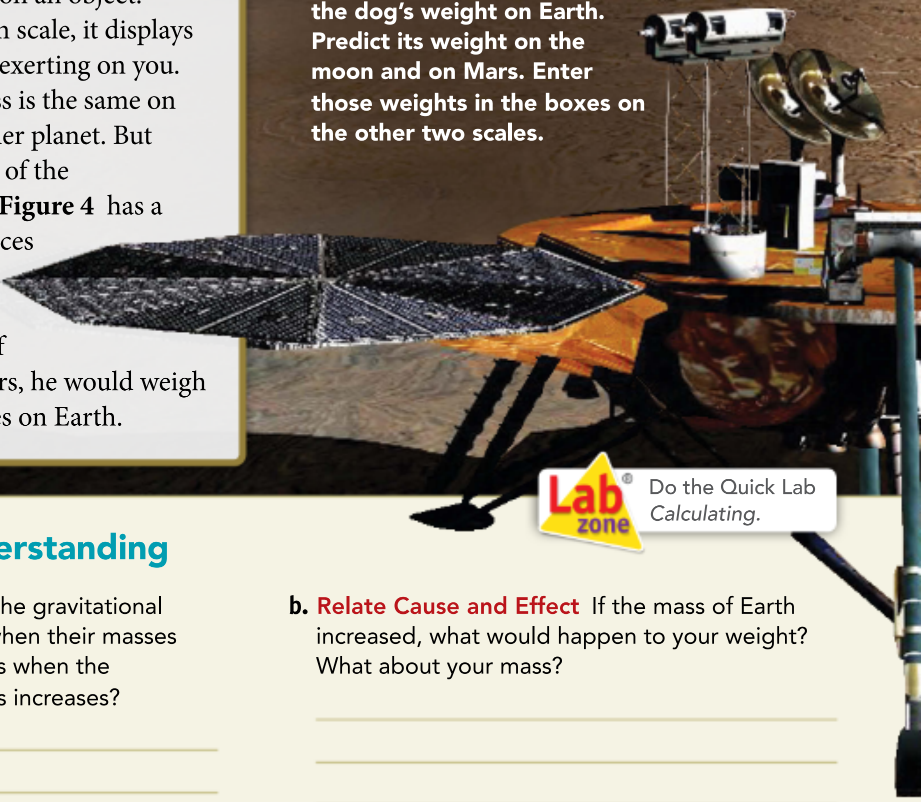


FIGURE 4
Weight and Mass
The Mars Phoenix Lander weighs about 3,400 N on Earth. It weighs about 1,300 N on Mars. **Predict** **The first scale shows the dog's weight on Earth. Predict its weight on the moon and on Mars. Enter those weights in the boxes on the other two scales.**

Lab zone Do the Quick Lab *Calculating.*

Assess Your Understanding

2a. Describe What happens to the gravitational force between two objects when their masses are increased? What happens when the distance between the objects increases?

____

____

____

b. Relate Cause and Effect If the mass of Earth increased, what would happen to your weight? What about your mass?

____

____

____

____

got it?

○ **I get it!** Now I know that the factors that affect the gravitational force between objects are ______________________________

○ I need extra help with ______________________________

Go to **MY SCIENCE COACH** *online for help with this subject.*

LESSON 3

Newton's Laws of Motion

UNLOCK THE BIG Q

- What Is Newton's First Law of Motion?
- What Is Newton's Second Law of Motion?
- What Is Newton's Third Law of Motion?

my planet Diary

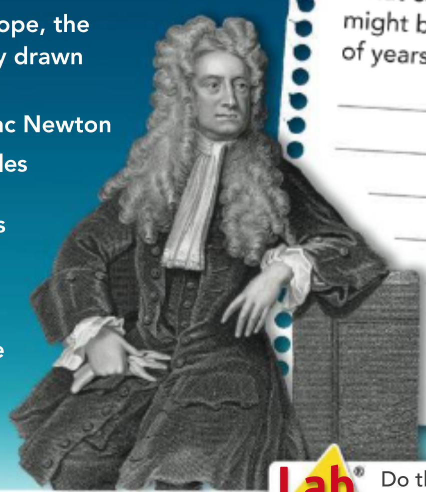
VOICES FROM HISTORY

Horse Force

"If a horse draws a stone tied to a rope, the horse (if I may so say) will be equally drawn back towards the stone...."

—Sir Isaac Newton

Scientists have used everyday examples to explain their ideas for hundreds of years. The quotation is from Newton's *Mathematical Principles of Natural Philosophy,* which was first published in the 1680s. Newton used this book to set down his laws of motion. These three simple laws describe much of the motion around you, and they continue to be studied today.



Answer the question below.

What current scientific discoveries might be taught in schools hundreds of years from now?

PLANET DIARY Go to **Planet Diary** to learn more about Newton.

Lab zone Do the Inquiry Warm-Up *What Changes Motion?*

What Is Newton's First Law of Motion?

You would be surprised if a rock started rolling on its own or a raindrop paused in midair. If an object is not moving, it will not start moving until a force acts on it. If an object is moving, it will continue at a constant velocity until a force acts to change its speed or its direction. **Newton's first law of motion states that an object at rest will remain at rest unless acted upon by a nonzero net force. An object moving at a constant velocity will continue moving at a constant velocity unless acted upon by a nonzero net force.**

Vocabulary
- inertia

Skills
Reading: Ask Questions
Inquiry: Infer

Inertia All objects, moving or not, resist changes in motion. Resistance to change in motion is called **inertia** (in UR shuh). Newton's first law of motion is also called the law of inertia. Inertia explains many common events, including why you move forward in your seat when the car you are in stops suddenly. You keep moving forward because of inertia. A force, such as the pull of a seat belt, is needed to pull you back. Roller coasters like the one in **Figure 1** have safety bars for the same reason.

Inertia Depends on Mass Some objects have more inertia than others. Suppose you need to move an empty backpack and a full backpack. The greater the mass of an object, the greater its inertia, and the greater the force required to change its motion. The full backpack is harder to move than the empty one because it has more mass and therefore more inertia.

FIGURE 1

Inertia

A roller coaster is hard to stop because it has a lot of inertia. **Infer** **Use Newton's fi rst law of motion to explain why you feel tossed around whenever a roller coaster goes over a hill or through a loop.**

Lab zone Do the Quick Lab *Around and Around.*

Assess Your Understanding

got it?

- I get it! Now I know that Newton's fi rst law of motion states that ________
- I need extra help with ________

Go to my science coach *online for help with this subject.*

What Is Newton's Second Law of Motion?

Which is harder to push, a full shopping cart or an empty one? Who can cause a greater acceleration on a shopping cart, a small child or a grown adult?

Changes in Force and Mass Suppose you increase the force on a cart without changing its mass. The acceleration of the cart will also increase. Your cart will also accelerate faster if something falls out. This reduces the mass of the cart, and you keep pushing just as hard. The acceleration of the sled in **Figure 2** will change depending on the mass of the people on it and the force the sled dogs apply. Newton realized these relationships and found a way to represent them mathematically.

Determining Acceleration **Newton's second law of motion states that an object's acceleration depends on its mass and on the net force acting on it.** This relationship can be written as follows.

$$\text{Acceleration} = \frac{\text{Net force}}{\text{Mass}}$$

This formula can be rearranged to show how much force must be applied to an object to get it to accelerate at a certain rate.

$$\text{Net force} = \text{Mass} \times \text{Acceleration}$$

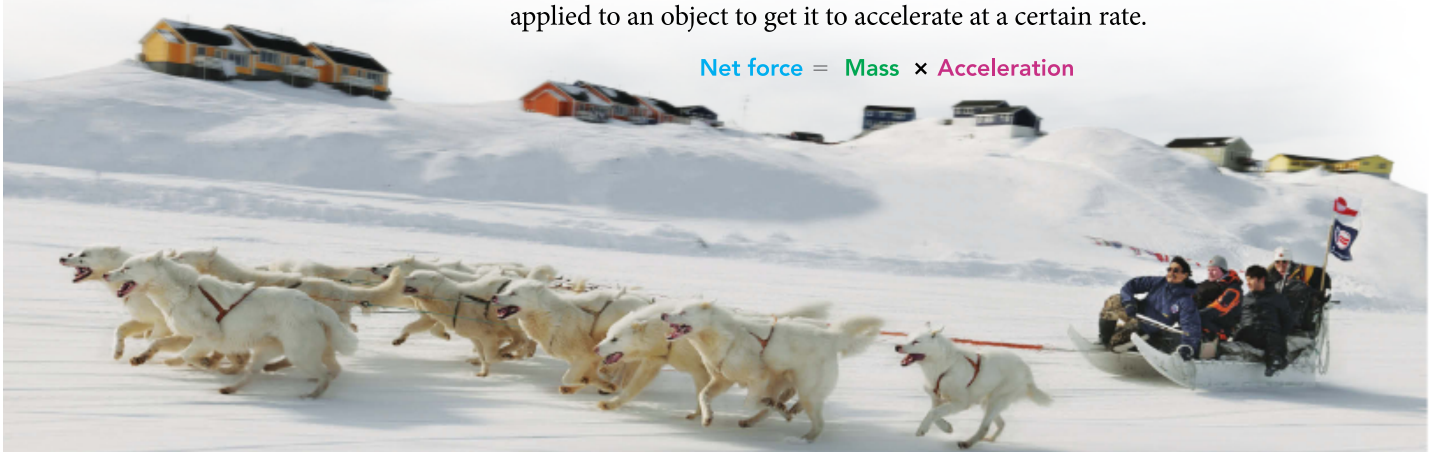


FIGURE 2

Newton's Second Law

Suppose that four dogs pull a sled carrying two people.

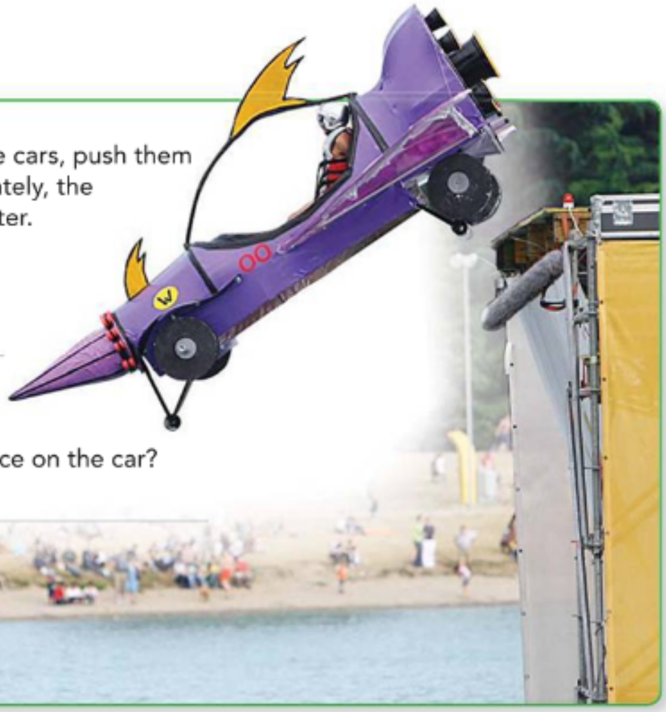
Explain Use words and fill in the pictures to show how you can change the dog/person arrangement to change the sled's acceleration.

How could you increase the sled's acceleration?

How could you decrease the sled's acceleration?

Acceleration is measured in meters per second per second (m/s^2Mass is measured in kilograms (kg). Newton's second law shows that force is measured in kilograms times meters per second per second (kg · m/s^2. This unit is also called the newton (N), which is the SI unit of force. One newton is the force required to give a 1-kg mass an acceleration of 1 m/s^2.

do the math!



Every year in cities around the world, teams create cars, push them across platforms, and hope they will fly. Unfortunately, the cars always end up accelerating down into the water.

1. **Calculate**

2. After that same car leaves the platform, gravity causes it to accelerate downward at a rate of 9.8 m/s^2. What is the gravitational force on the car?

Lab zone Do the Quick Lab *Newton's Second Law.*

Assess Your Understanding

1a. Review What equation allows you to calculate the force acting on an object?

b. Calculate What is the net force on a 2-kg skateboard accelerating at a rate of 2 m/s^2?

c. Predict If the mass of the skateboard doubled but the net force on it remained constant, what would happen to the acceleration of the skateboard?

got it?

○ **I get it!** Now I know that Newton's second law of motion describes the relationship

○ I need extra help with

Go to **my science coach** *online for help with this subject.*

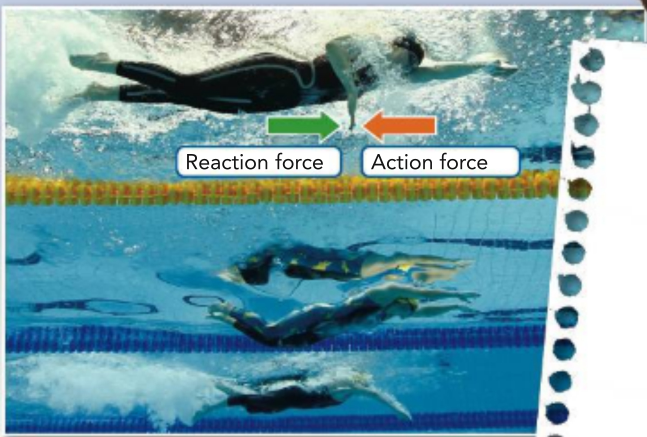


FIGURE 3

Action-Reaction Pairs

A swimmer moves because the water pushes her forward when she pushes back on it.

Interpret Diagrams **Draw arrows to show the action and reaction forces between the gymnast and the balance beam. Draw your own example in the space provided.**

What Is Newton's Third Law of Motion?

If you leaned against a wall and it didn't push back on you, you'd fall through. The force exerted by the wall is equal in strength and opposite in direction to the force you exert on the wall. **Newton's third law of motion states that if one object exerts a force on another object, then the second object exerts a force of equal strength in the opposite direction on the first object.** Another way to state Newton's third law is that for every action there is an equal but opposite reaction.

Action-Reaction Pairs Pairs of action and reaction forces are all around you. When you walk, you push backward on the ground with your feet. Think of this as an action force. (It doesn't matter which force is called the "action" force and which is called the "reaction" force.) The ground pushes forward on your feet with an equal and opposite force. This is the reaction force. You can only walk because the ground pushes you forward! In a similar way, the swimmer in **Figure 3** moves forward by exerting an action force on the water with her hands. The water pushes on her hands with an equal reaction force that propels her body forward.

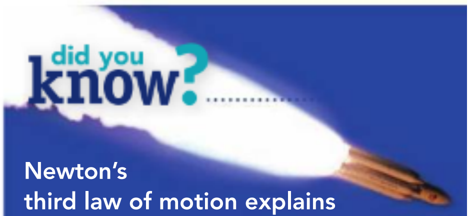
Ask Questions Action and reaction force pairs are all around you, but they aren't always obvious. Write down a question about a situation in which you can't identify what force pairs are at work.

Detecting Motion If you drop your pen, gravity pulls the pen downward. According to Newton's third law, the pen pulls Earth upward with an equal and opposite reaction force. You see the pen fall. You *don't* see Earth accelerate toward the pen. Remember Newton's second law. If mass increases and force stays the same, acceleration decreases. The same force acts on both Earth and your pen. Since Earth has such a large mass, its acceleration is so small that you don't notice it.

Do Action-Reaction Forces Cancel? You have learned that two equal forces acting in opposite directions on an object cancel each other out and produce no change in motion. So why don't the action and reaction forces in Newton's third law of motion cancel out as well?

Action and reaction forces do not cancel out because they act on different objects. The swimmer in **Figure 3** exerts a backward action force on the water. The water exerts an equal but opposite forward reaction force on her hands. The action and reaction forces act on different objects—the action force acts on the water and the reaction force acts on her hands.

Unlike the swimmer and the water, the volleyball players in **Figure 4** both exert a force on the *same* object—the volleyball. Each player exerts a force on the ball equal in strength but opposite in direction. The forces on the volleyball are balanced. The ball does not move toward one player or the other.



did you know?

Newton's third law of motion explains why rockets accelerate in space, even though there is no water or air to push off of. Inside rockets, gas is produced. When the rockets push that gas backward out of the rocket, a reaction force occurs that pushes the rocket forward.

FIGURE 4

Action-Reaction Forces

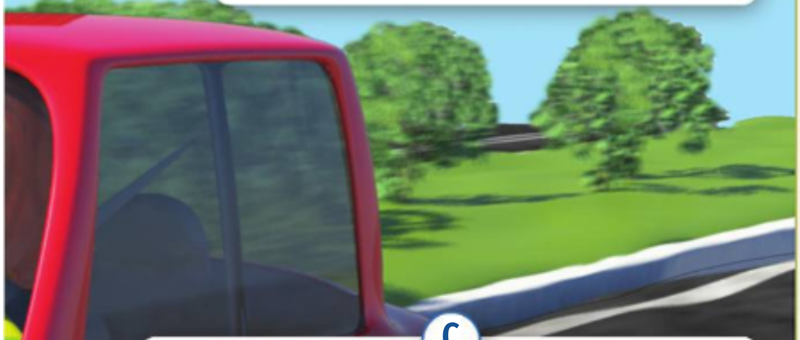
All the horizontal forces on the volleyball cancel out.

Apply Concepts In the dog illustration above, use Newton's third law of motion to draw and label any missing force arrows for all the objects.

B

Vroom!

The driver hates killing bugs. When she saw one coming toward the windshield, she braked suddenly and hoped it would get out of the way. (Sadly, it did not.) When she hit the brakes, she felt that she was thrown forward. Use one of Newton's laws to explain why.

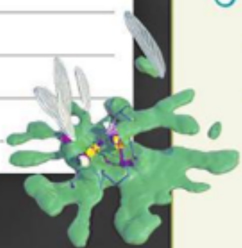


C

Splat!

The unfortunate bug hits the windshield with a force of 1 N. If you call this the action force, what is the reaction force? Does the car hit the bug any harder than the bug hits the car? Use one of Newton's laws to explain why or why not.

Compare the forces on the bug and the car again. Use another one of Newton's laws to explain why the bug goes *splat* and the car keeps going, without noticeably slowing down.



Lab zone Do the Quick Lab *Interpreting Illustrations.*

Assess Your Understanding

2a. Identify A dog pulls on his leash with a 10-N force to the left, but doesn't move. Identify the reaction force.

b. ANSWER THE BIG ? Using all three of Newton's laws, explain how objects react to forces.

got it?

- **I get it!** Now I know that Newton's third law of motion states that
- I need extra help with

Go to **MY SCIENCE COACH** *online for help with this subject.*

LESSON 4

Momentum

UNLOCK THE BIG Q

What Is an Object's Momentum?

my planet Diary

FUN FACTS

Air Hockey Science

Whoosh—you've just scored a goal! The puck is about to go back into play. How can you keep the puck out of your goal and get it back into your opponent's? One of the factors you have to consider is momentum. Momentum is a physical quantity that all moving objects have. If you know about momentum, you can predict how an object will act when it collides with other objects. With some quick scientific thinking, you can get the puck to bounce all over the table and back into your opponent's goal!

Lab zone® Do the Inquiry Warm-Up *How Pushy Is a Straw?*

Answer the questions below.

1. Why might it be better to try to bounce a puck off the wall rather than shoot it straight into your opponent's goal?

____

____

____

____

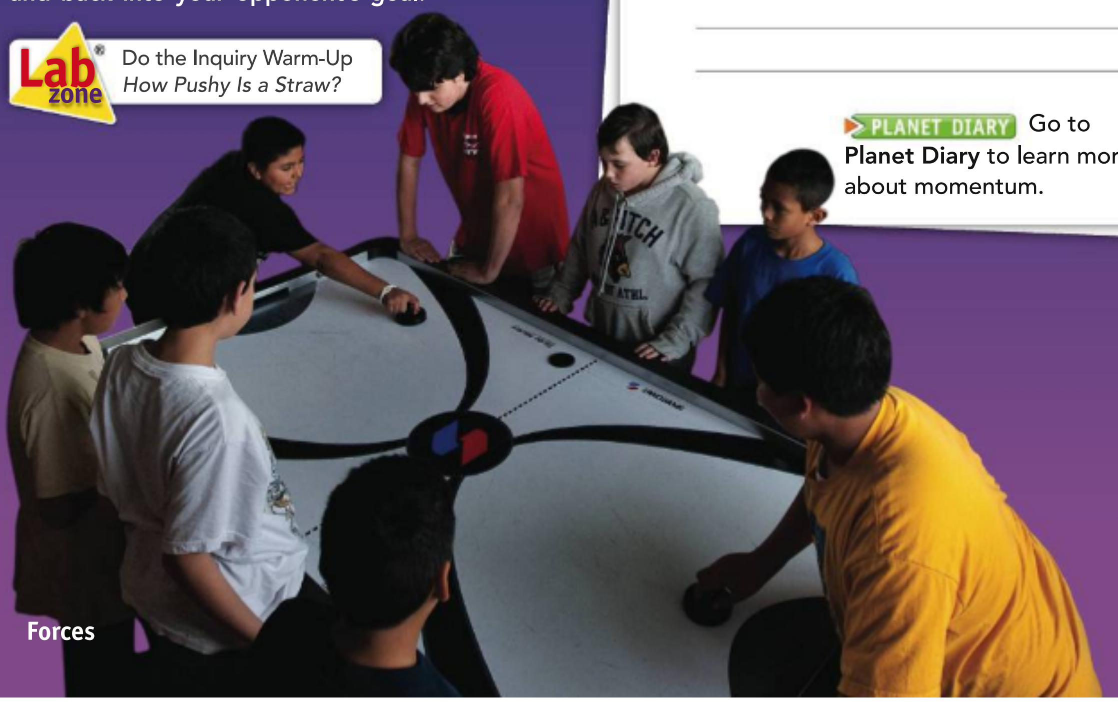
2. Where else could it be helpful to know how objects act after colliding?

____

____

____

PLANET DIARY Go to **Planet Diary** to learn more about momentum.



Vocabulary
- momentum
- law of conservation of momentum

Skills
- Reading: Identify the Main Idea
- Inquiry: Calculate

What Is an Object's Momentum?

Is it harder to stop a rolling bowling ball or a rolling marble? Does your answer depend on the velocities of the objects? All moving objects have what Newton called a "quantity of motion." Today it's called momentum. **Momentum** (moh MEN tum) is a characteristic of a moving object that is related to the mass and the velocity of the object. **The momentum of a moving object can be determined by multiplying the object's mass by its velocity.**

Momentum = Mass × Velocity

Since mass is measured in kilograms and velocity is measured in meters per second, the unit for momentum is kilograms times meters per second (kg · m/s). Like velocity, acceleration, and force, momentum is described by both a direction and a strength. The momentum of an object is in the same direction as its velocity.

The more momentum a moving object has, the harder it is to stop. For example, a 0.1-kg baseball moving at 40 m/s has a momentum of 4 kg·m/s in the direction it's moving.

Momentum = 0.1 kg × 40 m/s

Momentum = 4 kg·m/s

But a 1,200-kg car moving at the same speed as the baseball has a much greater momentum: 48,000 kg· m/s. The velocity of an object also affects the amount of momentum it has. For example, a tennis ball served by a professional tennis player has a large momentum. Although the ball has a small mass, it travels at a high velocity.

Word Origins *Momentum* comes from the Latin word *movere*. Based on the definition of momentum, which of these is the definition of *movere*?
- ◯ to spin
- ◯ to move
- ◯ to sit

apply it!

Calculate In each question below, calculate the desired quantity.

1 The lioness has a mass of 180 kg and a velocity of 16 m/s to the right. What is her momentum?

2 The warthog has a mass of 100 kg. What does the warthog's speed have to be for it to have the same momentum as the lioness?

Identify the Main Idea Circle a sentence that relates the main idea of this section to two colliding cars. Then underline two supporting examples.

Conservation of Momentum

Imagine you're driving a go-cart. If you ran into another go-cart that was at rest and got stuck to it, what do you think would happen to your momentum? Before you hit the other go-cart, your momentum was just your mass times your velocity. How has the additional mass changed that momentum? It actually hasn't changed it at all!

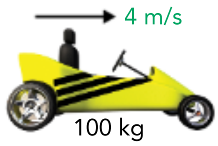
A quantity that is conserved is the same after an event as it was before. The law of conservation of momentum states that, in the absence of outside forces like friction, the total momentum of objects that interact does not change. The amount of momentum two cars have is the same before and after they interact. **The total momentum of any group of objects remains the same, or is conserved, unless outside forces act on the objects.**

FIGURE 1

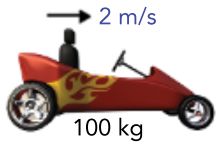
INTERACTIVE ART Conservation of Momentum

Calculate Complete the equations describing the momentum of each collision. Identify the direction in each case.

Before



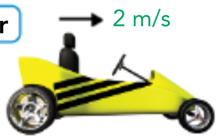
Momentum = 400 kg·m/s to the right



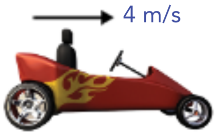
Momentum = 200 kg·m/s to the right

Total momentum = ________ kg·m/s ________________

After



Momentum = ________ kg·m/s to the right



Momentum = ________ kg·m/s to the right

Total momentum = ________ kg·m/s ________________

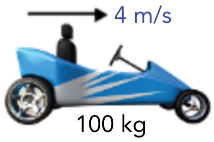
"Non-Sticky" Collisions

Look at this example of a collision. When two objects of the same mass don't stick together and outside forces (such as friction) are negligible, the objects just trade velocities. The car that is going faster before the collision will end up slowing down, and the car that is going slower before the collision will end up speeding up.

"Sticky" Collisions

Sometimes objects end up sticking together during a collision. These two cars, which have the same mass, got tangled together after they collided. Since the green car was at rest and had a momentum of zero, only the blue car had any momentum before the collision. After they collided and stuck together, the cars shared that momentum. The total momentum of the two cars stayed the same.

Before



Momentum = ________ kg·m/s to the right   Momentum = ________ kg·m/s

Total momentum = ________ kg·m/s ________________

After

Total mass = ________________

Total momentum = ________________ kg·m/s ________________

What must the velocity be? ________________________

Lab zone Do the Quick Lab *Colliding Cars.*

Assess Your Understanding

1a. **Explain** How can a heavy moving van have the same momentum as a small motorcycle?

____

b. **Calculate** What is the momentum of a 750-kg car traveling at a velocity of 25 m/s?

____

c. **Infer** The total momentum of two marbles before a collision is 0.06 kg·m/s. No outside forces act on the marbles. What is the total momentum of the marbles after the collision?

____

got it?

○ **I get it!** Now I know that momentum is conserved unless ________________

○ I need extra help with ________________

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LESSON 5

Free Fall and Circular Motion

- What Is Free Fall?
- What Keeps a Satellite in Orbit?

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Finding Yourself

The GPS (Global Positioning System) is a "constellation" of satellites that orbit 10,600 miles above Earth. The GPS makes it possible for people with ground receivers to pinpoint their geographic location. The first GPS satellites were placed in orbit in 1978. These early satellites were expected to operate for approximately five years. Newer satellites have an expected lifespan of seven to eight years.

GPS Satellites in Orbit

Years	Number of GPS Satellites Launched	Number of Operating GPS Satellites
1978–1982	6	6
1983–1987	4	8
1988–1992	17	21
1993–1997	12	27
1998–2002	5	28
2003–2007	11	31

SCIENCE STATS

Interpret Data Use the data in the table to answer the questions below.

1. What is the total number of satellites launched from 1978 to 2007? How many were still operating as of 2007?

2. How many satellites stopped operating between 2003 and 2007?

PLANET DIARY Go to **Planet Diary** to learn more about the GPS.

Lab zone Do the Inquiry Warm-Up *What Makes an Object Move in a Circle?*

Vocabulary
- free fall
- satellite
- centripetal force

Skills
- Reading: Relate Cause and Effect
- Inquiry: Create Data Tables

What Is Free Fall?

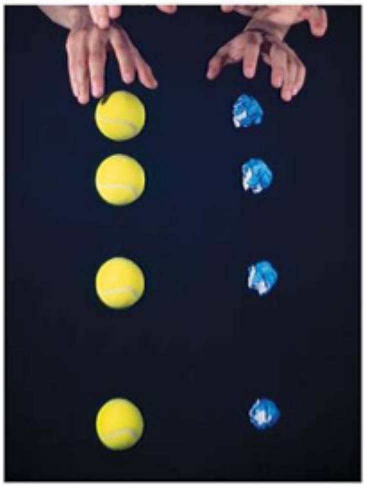
When the only force acting on an object is gravity, the object is said to be in **free fall.** The force of gravity causes the object to accelerate. **Free fall is motion where the acceleration is caused by gravity.** When something falls on Earth, there is fluid friction from the air around it. This friction acts against gravity, reducing the acceleration of falling objects. Air friction increases as an object falls. If an object falls for long enough, increased air friction will reduce its acceleration to zero. The object will continue to fall, but it will fall at a constant velocity.

Near the surface of Earth, the acceleration due to gravity is 9.8 m/s2. If there were no air friction, a falling object would have a velocity of 9.8 m/s after one second and 19.6 m/s after two seconds. Since air friction reduces acceleration, an object falling on Earth for one second will actually have a velocity that is less than 9.8 m/s.

FIGURE 1

Free Fall

The photo shows a tennis ball and a crumpled piece of paper of different masses as they fall during a fraction of a second. If the only force acting on them were gravity, they would fall at exactly the same rate and line up perfectly. H owever, air friction is also p resent. Air friction has a greater effect on the paper's acceleration than on the tennis ball's a cceleration. This causes the tennis ball to fall faster.



do the math!

Create Data Tables

Suppose you had a chamber with no air, eliminating the force of air friction. Complete the table below for an object that is dropped from rest. Remember the formula Velocity = Acceleration × Time. The acceleration due to gravity is 9.8 m/s ^{2}.

Time (s)	Velocity (m/s)
0	
1	
2	
3	
4	

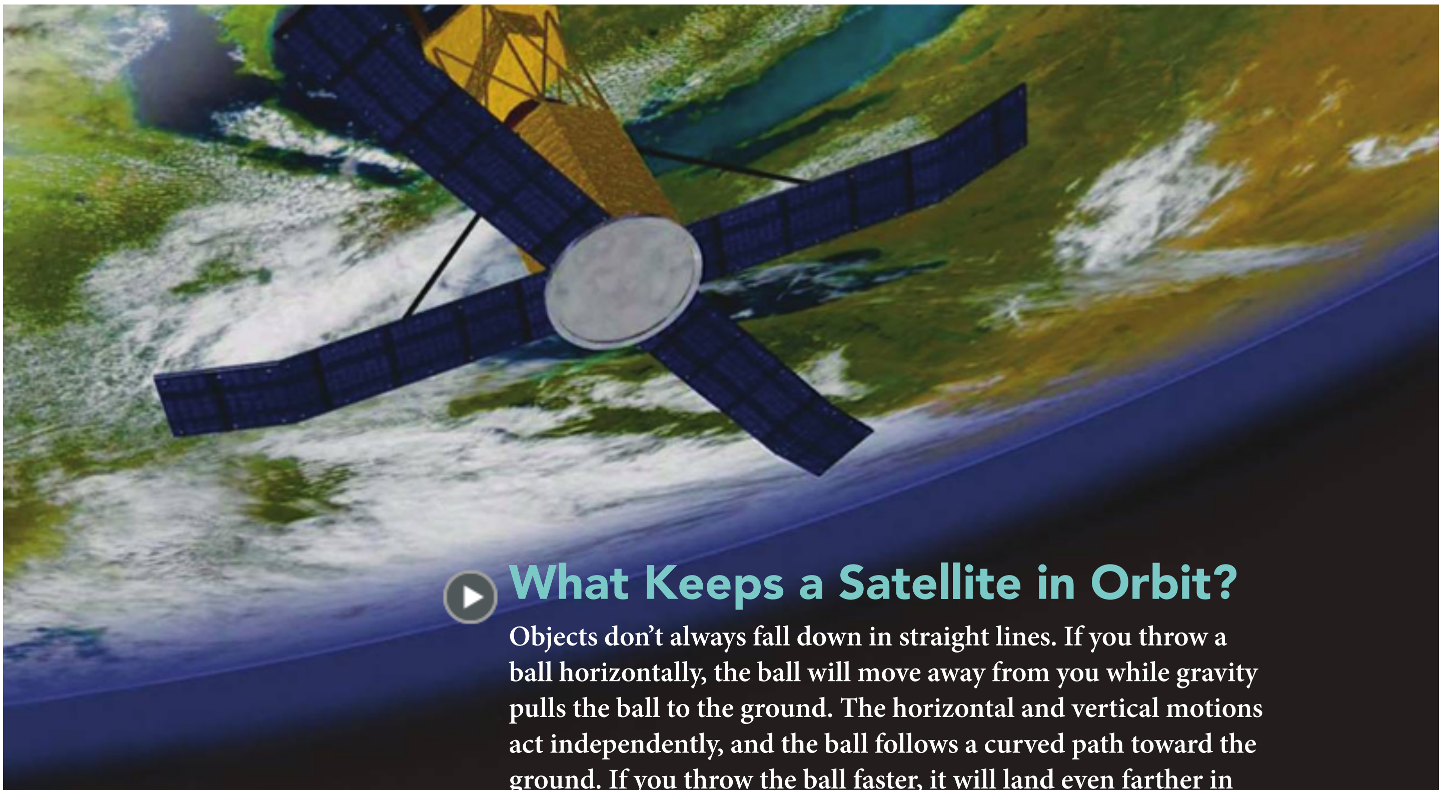
Lab zone® Do the Quick Lab *Which Lands First?*

Assess Your Understanding

got it?

- I get it! Now I know that free fall is ______
- I need extra help with ______

Go to MY SCIENCE COACH *online for help with this subject.*



What Keeps a Satellite in Orbit?

Objects don't always fall down in straight lines. If you throw a ball horizontally, the ball will move away from you while gravity pulls the ball to the ground. The horizontal and vertical motions act independently, and the ball follows a curved path toward the ground. If you throw the ball faster, it will land even farther in front of you. The faster you throw an object, the farther it travels before it lands.

Relate Cause and Effect
On the next page, underline the effect a centripetal force has on an object's motion. Circle the effect of turning off a centripetal force.

Satellite Motion This explains how satellites, which are objects that orbit around other objects in space, follow a curved path around Earth. What would happen if you were on a high mountain and could throw a ball as fast as you wanted? The faster you threw it, the farther away it would land. But, at a certain speed, the curved path of the ball would match the curved surface of Earth. Although the ball would keep falling due to gravity, Earth's surface would curve away from the ball at the same rate. The ball would fall around Earth in a circle, as shown in **Figure 2.**

FIGURE 2

Satellite Motion

A satellite launched from Earth enters orbit because the curve of its path matches the curved surface of Earth.

Make Models On the picture at the right, draw arrows representing the gravitational force on the ball at each point.

CHALLENGE Explain why Earth's atmosphere would prevent this baseball from ever actually being thrown into orbit. Why is this not a problem for satellites?

___

___

___

Satellites in orbit around Earth continuously fall toward Earth, but because Earth is curved they travel around it. In other words, a satellite is a falling object that keeps missing the ground! It falls around Earth rather than onto it. Once it has entered a stable orbit, a satellite does not need fuel. It continues to move ahead due to its inertia. At the same time, gravity continuously changes the satellite's direction. Most satellites are launched at a speed of about 7,900 m/s. That's more than 17,000 miles per hour!

Centripetal Force

Many manufactured satellites orbit Earth in an almost circular path. Recall that an object traveling in a circle is accelerating because it constantly changes direction. If an object is accelerating, a force must be acting on it. A force that causes an object to move in a circular path is a **centripetal force** (sen TRIP ih tul). The word *centripetal* means "center-seeking." Centripetal forces always point toward the center of the circle an object is moving in. If you could turn off a centripetal force, inertia would cause the object to fly off in a straight line. For example, the string of a yo-yo being swung in a circle provides a centripetal force. Cutting the string would cut off the centripetal force, and the yo-yo would fly off in a straight line.

apply it!

Identify What is creating the centripetal force in each situation below?

1. A tetherball swinging around a pole

2. Mars orbiting around the sun

3. A child standing on a merry-go-round

Lab zone: Do the Quick Lab *Orbiting Earth.*

Assess Your Understanding

1a. Identify What is the force that causes objects to move in circles?

b. Predict If Earth's gravity could be turned off, what would happen to satellites that are currently in orbit? Explain your reasoning.

got it?

○ **I get it!** Now I know that satellites stay in orbit because

○ I need extra help with

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LESSON

1 Work and Power

UNLOCK THE BIG Q

- How Is Work Defined?
- What Is Power?

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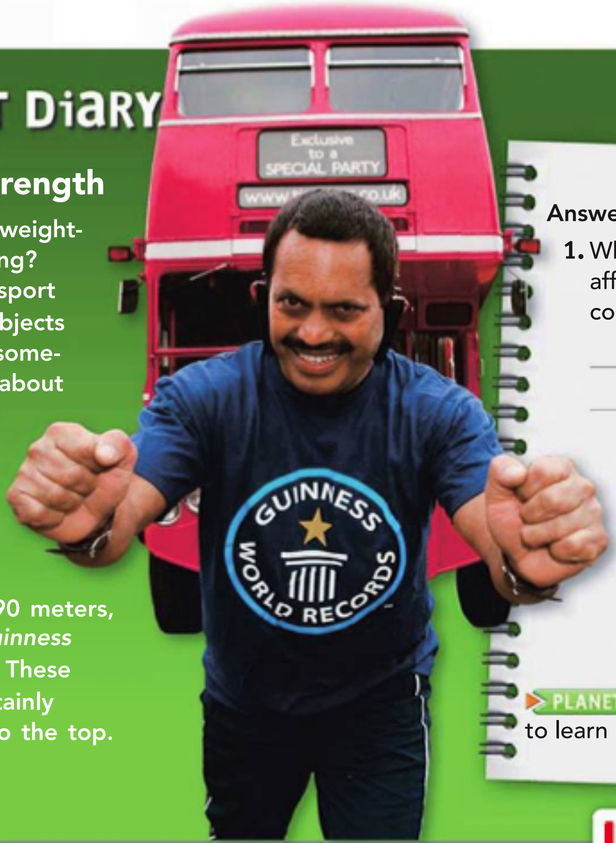
Feats of Strength

You've heard of weight-lifting, but bus-pulling? People have made a sport out of pulling huge objects using their muscles—sometimes their ears! Talk about extreme sports!

Manjit Singh used his ears to drag this double-decker bus for 5 meters. David Huxley pulled an airplane for more than 90 meters, landing him in the *Guinness World Records* book. These competitors have certainly worked hard to get to the top.



FUN FACT

Answer the questions below.

1. What factors might have affected how much work these competitors did?

______

______

2. Name an everyday task that you would consider to be a lot of work.

______

______

PLANET DIARY Go to **Planet Diary** to learn more about feats of strength.

Lab zone Do the Inquiry Warm-Up *Pulling at an Angle.*

How Is Work Defined?

If you push a child on a swing, you are doing work on the child. If you pull your books out of your backpack, you do work on your books. In scientific terms, you do **work** any time you exert a force on an object that causes the object to move some distance. **Work is done on an object when the object moves in the same direction in which the force is exerted.**

Vocabulary
- work
- joule
- power
- watt

Skills
- Reading: Identify Supporting Evidence
- Inquiry: Calculate

No Work Without Motion Suppose you push on a car that is stuck in the mud. You certainly exert a force on the car, so it might seem as if you do work. But if the force you exert does not make the car move, you are not doing any work on it. To do work on an object, the object must move some distance as a result of your force. If the object does not move, no work is done, no matter how much force is exerted.

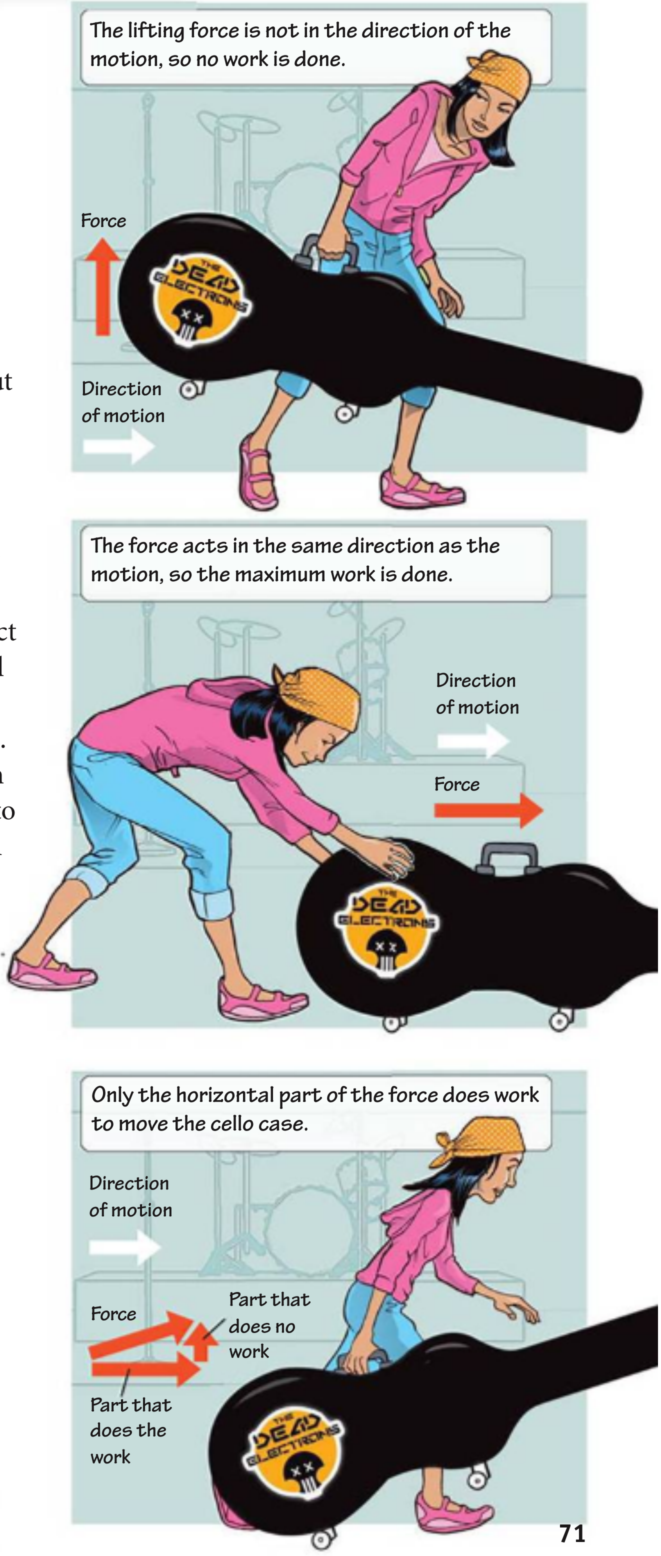
Force in the Same Direction Think about carrying your backpack to school in the morning. You know that you exert a force on your backpack when you carry it, but you do not do any work on it. To do work on an object, the force you exert must be in the same direction as the object's motion. When you carry an object while walking at constant velocity, you exert an upward force on the object. The motion of the object is in the horizontal direction. Since the force is vertical and the motion is horizontal, you don't do any work.

Figure 1 shows three different ways to move a cello. You can lift it off the ground and carry it, you can push it parallel to the ground, or you can pull it at an angle to the ground. The weight of the cello is the same in each situation, but the amount of work varies.

FIGURE 1

Force, Motion, and Work

The amount of work that you do on something depends on the direction of your force and the object's motion. **Describe Suppose you are moving a rolling suitcase. Describe three ways of moving it that require different amounts of work.**



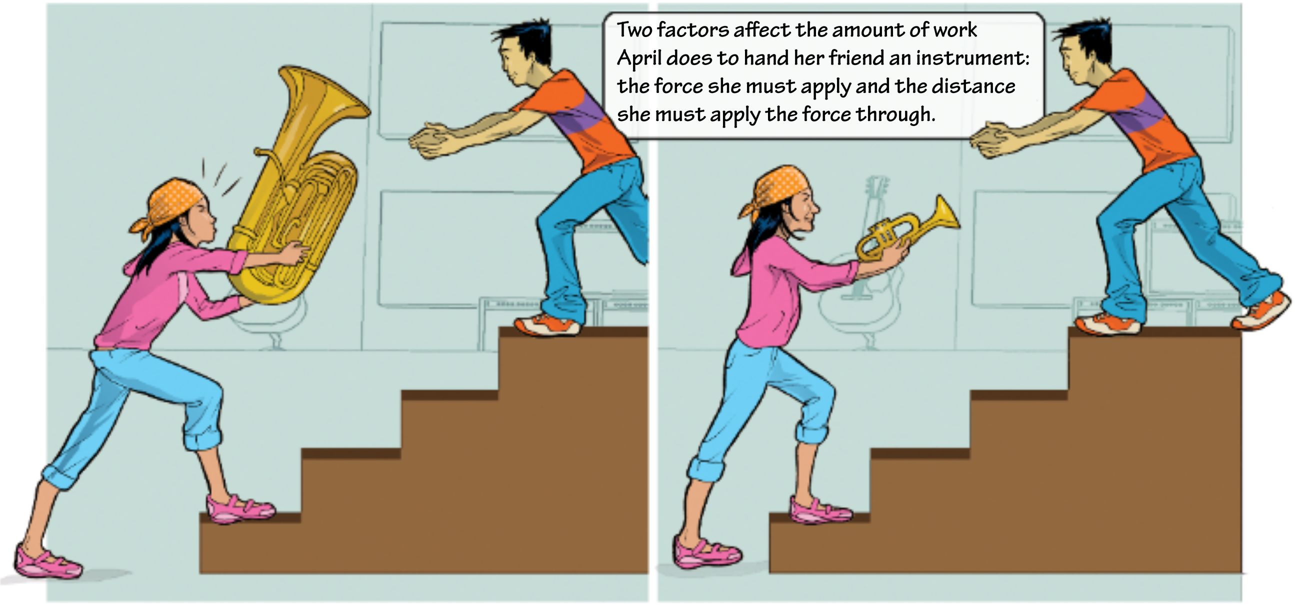


FIGURE 2

INTERACTIVE ART **Amount of Work**

When April lifts a trumpet or a tuba up the stairs, she does work.

Draw Conclusions **If April's friend wanted to reduce the amount of work April needed to do to hand the trumpet to him, where could he stand? Circle the step(s). If the stage were higher, what would happen to the total amount of work required to lift the trumpet from the floor to the stage?**

Calculating Work

Look at **Figure 2**. Which do you think involves more work: lifting a 40-newton tuba up three steps (about 0.5 meters), or lifting a 5-newton trumpet up the same three steps? Your common sense may suggest that lifting a heavier object requires more work than lifting a lighter object. This is true. But is it more work to lift an instrument up three steps or up to the top story of a building? As you might guess, moving an object a greater distance requires more work than moving the same object a shorter distance.

The amount of work you do depends on both the amount of force you exert and the distance the object moves. **The amount of work done on an object can be determined by multiplying force times distance.**

Work = Force × Distance

When you lift an object, the upward force you exert must be at least equal to the object's weight. So, to lift the trumpet, you would have to exert a force of 5 newtons. The distance you lift the trumpet is 0.5 meters. The amount of work you do on the trumpet can be calculated using the work formula.

Work = Force × Distance

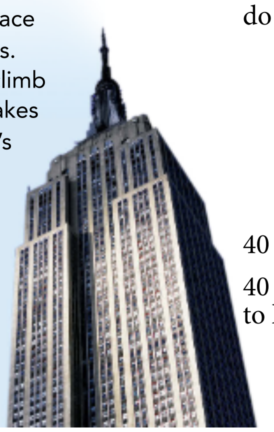
Work = 5N × 0.5m

Work = 2.5N• m

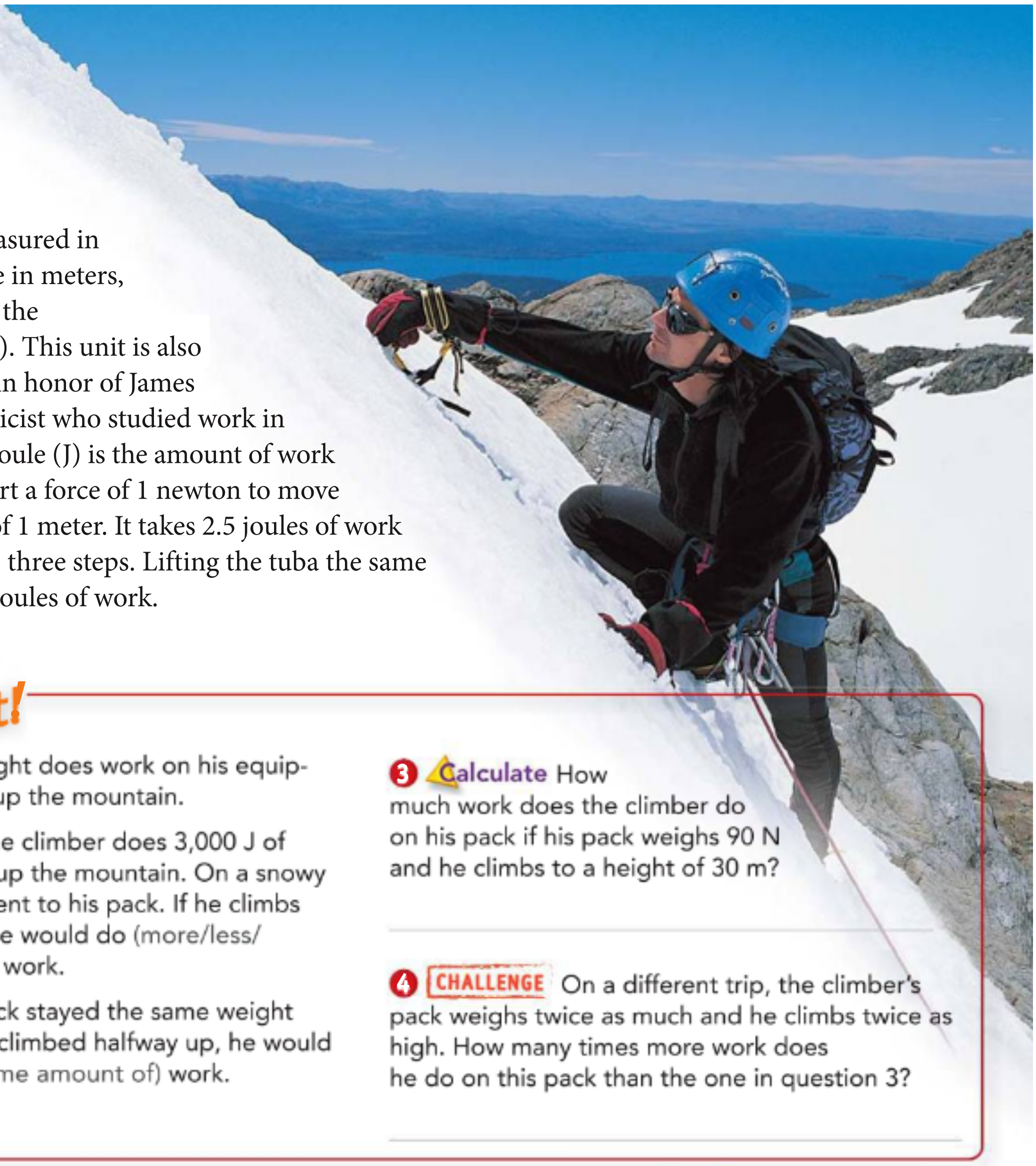
To lift the tuba, you would have to exert a force of 40 newtons. So the amount of work you do would be 40 newtons × 0.5 meters, or 20N • m. You do more work to lift the heavier object.

did you know?

Participants in the Empire State Building Run-Up race up the skyscraper's stairs. For a 500 N person to climb 1,576 steps (320 m) it takes 160,000 J of work. That's enough work to lift an elephant over 3 m!



When force is measured in newtons and distance in meters, the SI unit of work is the newton-meter (N m). This unit is also called a **joule** (jool) in honor of James Prescott Joule, a physicist who studied work in the mid-1800s. One joule (J) is the amount of work you do when you exert a force of 1 newton to move an object a distance of 1 meter. It takes 2.5 joules of work to lift the trumpet up three steps. Lifting the tuba the same distance requires 20 joules of work.



apply it!

The climber on the right does work on his equipment as he carries it up the mountain.

1 On a warm day, the climber does 3,000 J of work to get his pack up the mountain. On a snowy day, he adds equipment to his pack. If he climbs to the same height, he would do (more/less/the same amount of) work.

2 If the climber's pack stayed the same weight and the climber only climbed halfway up, he would do (more/less/the same amount of) work.

3 **Calculate** How much work does the climber do on his pack if his pack weighs 90 N and he climbs to a height of 30 m?

4 **CHALLENGE** On a different trip, the climber's pack weighs twice as much and he climbs twice as high. How many times more work does he do on this pack than the one in question 3?

Lab zone Do the Quick Lab *What is Work?*

Assess Your Understanding

1a. Describe A waiter carries a 5-newton tray of food while he walks a distance of 10 meters. Is work done on the tray? Why or why not?

b. Explain You're holding your dog's leash and trying to stand still as he pulls on the leash at an angle. You move forward. (All of/Some of/None of) his force does work on you.

c. Calculate How much work do you do when you push a shopping cart with a force of 50 N for a distance of 5 m?

got it?

○ **I get it!** Now I know that work is

○ I need extra help with

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What Is Power?

If you carry a backpack up a flight of stairs, the work you do is the same whether you walk or run. The amount of work you do on an object is not affected by the time it takes to do the work. But scientists keep track of how fast work is done with a rate called power.

Power **is the rate at which work is done.** **Power equals the amount of work done on an object in a unit of time.** You need more power to run up the stairs with your backpack than to walk because it takes you less time to do the same work.

You can think of power in another way. An object that has more power than another object does more work in the same time. It can also mean doing the same amount of work in less time.

Identify Supporting Evidence Underline details and examples that support the main idea of this section.

Calculating Power Whenever you know how fast work is done, you can calculate power. Power is calculated by dividing the amount of work done by the amount of time it takes to do the work. This can be written as the following formula.

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

Since work is equal to force times distance, you can rewrite the equation for power as follows.

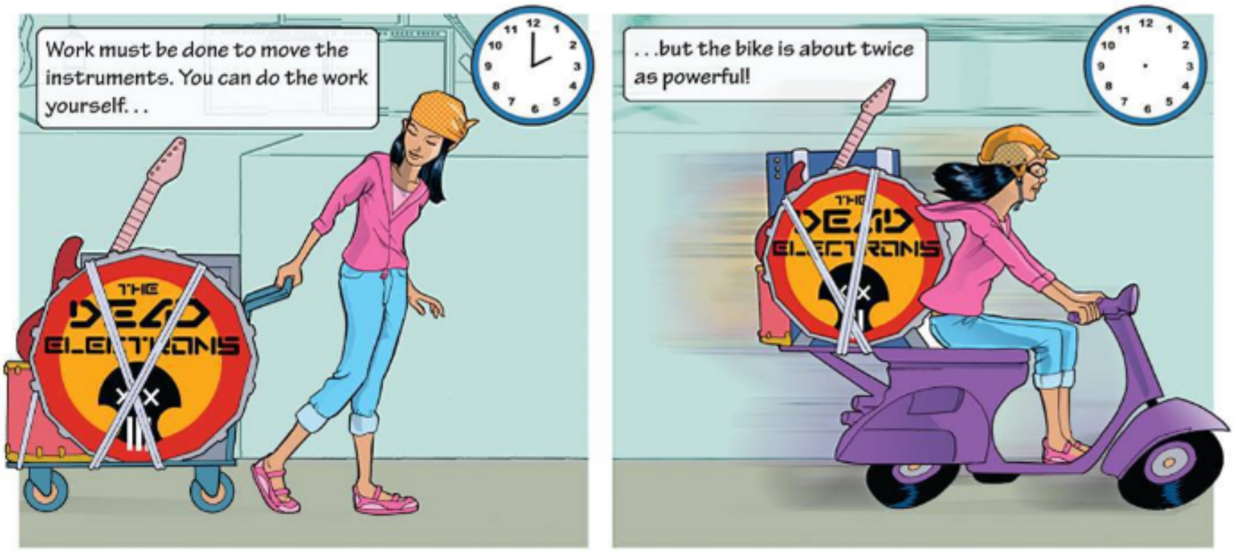
$$\text{Power} = \frac{\text{Force} \times \text{Distance}}{\text{Time}}$$

FIGURE 3

Work and Power

April carried her moving boxes up a flight of stairs. Notice how much time it took her.

Estimate Suppose April ran instead. Fill in the second panel to show how much time it would take her.



Power Units You may have heard car advertisements mention horsepower. The term isn't misleading. It's the same kind of power you just learned how to calculate. When work is measured in joules and time in seconds, the SI unit of power is the joule per second (J/s). This unit is also known as the watt (W). One joule of work done in one second is one watt of power. In other words, 1 J/s = 1 W. A watt is very small, so power is often measured in larger units such as kilowatts or horsepower. One kilowatt (kW) equals 1,000 watts. One horsepower equals 746 watts.

Vocabulary Identify Multiple Meanings What is the scientific meaning of *power*?

do the math!

When a tow truck pulls a car, it applies a force over a distance. Work is done in a horizontal direction. **Calculate** Complete the table by calculating the power of the tow truck in each case.

Recall the formula for power is

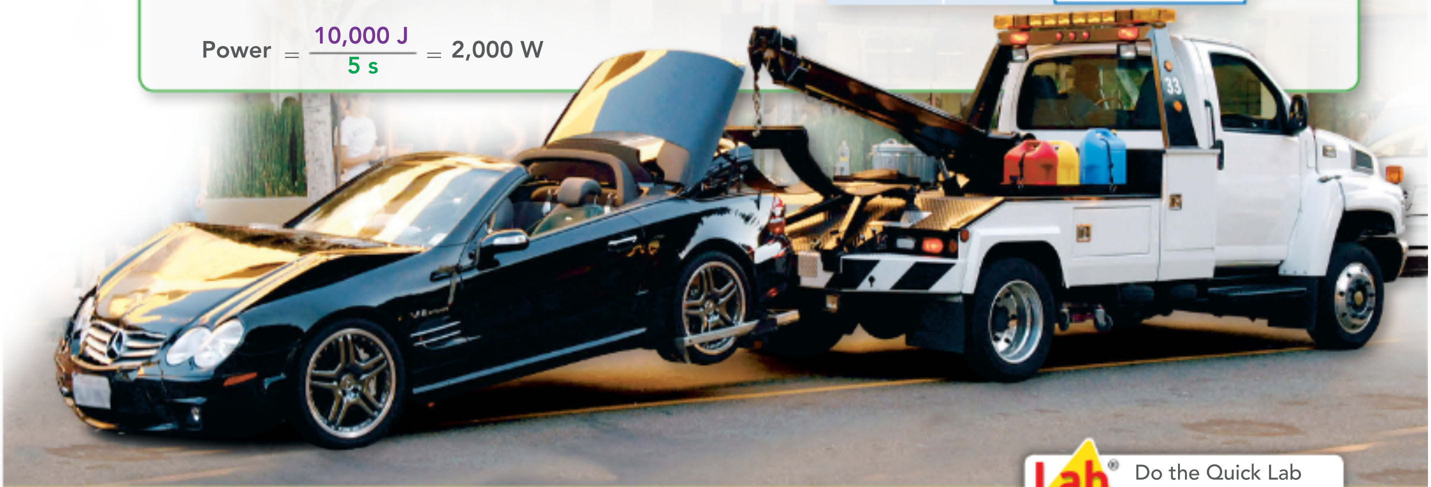
$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$

If a tow truck does 10,000 J of work in 5 seconds, then the power of the truck is calculated as follows.

$$\text{Power} = \frac{10{,}000\ \text{J}}{5\ \text{s}} = 2{,}000\ \text{W}$$

Tow Truck Power

Work (J)	Time (s)	Power (W)
120,000	60	
69,000	30	
67,500	45	



Lab zone Do the Quick Lab *Investigating Power.*

Assess Your Understanding

got it?

- O **I get it!** Now I know that power
- O I need extra help with

Go to **my science coach** *online for help with this subject.*

LESSON 2

Understanding Machines

UNLOCK THE BIG Q

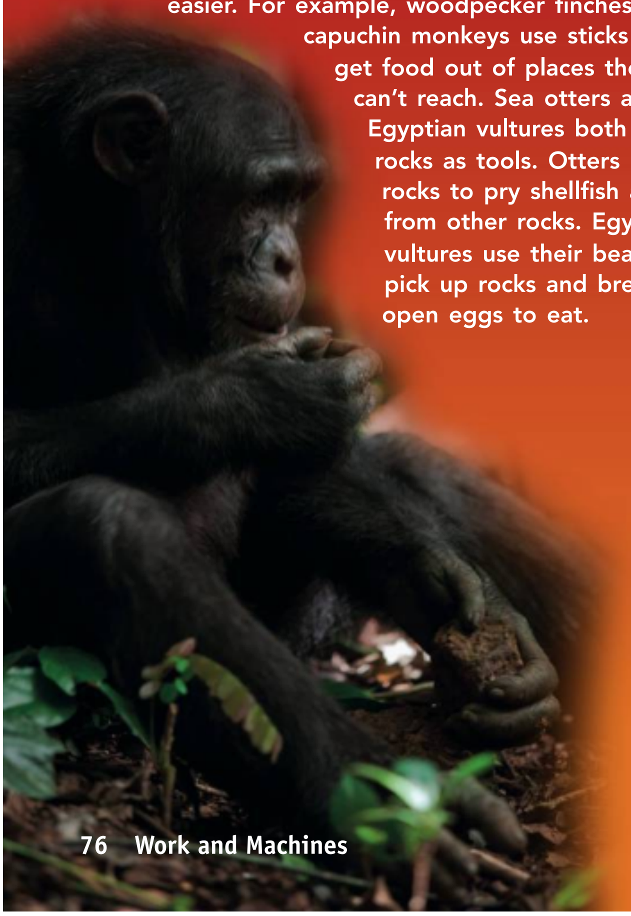
- What Does a Machine Do?
- What Is Mechanical Advantage?
- What Is Efficiency?

my planet Diary

Sticks and Stones

When you need to peel an apple or open a can of soup, you reach for the right tool to do the job.

Some animals use items such as sticks and rocks to make finding or eating their food easier. For example, woodpecker finches and capuchin monkeys use sticks to get food out of places they can't reach. Sea otters and Egyptian vultures both use rocks as tools. Otters use rocks to pry shellfish away from other rocks. Egyptian vultures use their beaks to pick up rocks and break open eggs to eat.



FUN FACT

Communicate Discuss these questions with a partner. Write your answers below.

1. How does the rock make it easier for the chimpanzee in the photo to crack open nuts?

2. What human tools would you use to do the same job?

PLANET DIARY Go to Planet Diary to learn more about tools.

Lab zone Do the Inquiry Warm-Up *Is It a Machine?*

Vocabulary

- machine
- input force
- output force
- mechanical advantage
- efficiency

Skills

- Reading: Compare and Contrast
- Inquiry: Predict

What Does a Machine Do?

What do you picture when you hear the word *machine*? You may think of machines as complex gadgets with motors, but a machine can be as simple as a ramp. **Machines** are devices that allow you to do work in an easier way. Machines do not reduce the amount of work you do. Instead, they just change the way you do work. In **Figure 1,** April does the same amount of work to move her speaker onto the stage whether or not she uses a ramp. The ramp makes that work easier. **A machine makes work easier by changing at least one of three factors: the amount of force you exert, the distance over which you exert your force, or the direction in which you exert your force.**

Input Versus Output

When you do work, the force you exert is called the **input force.** You exert your input force over the input distance. In **Figure 1B,** April's input force is the force she uses to pull the speaker up the ramp. The input distance is the length of the ramp. The machine exerts the **output force** over the output distance. The weight of the speaker is the output force. The height of the ramp is the output distance. Input force times input distance equals input work. Output force times output distance equals output work. Since machines do not reduce the work you do, your output work can never be greater than your input work.

FIGURE 1

Using Machines

Using a ramp makes it easier for April to move the speaker onto the stage.

Interpret Diagrams In Figure 1B, draw a line that represents April's output distance and an arrow that represents her output force.

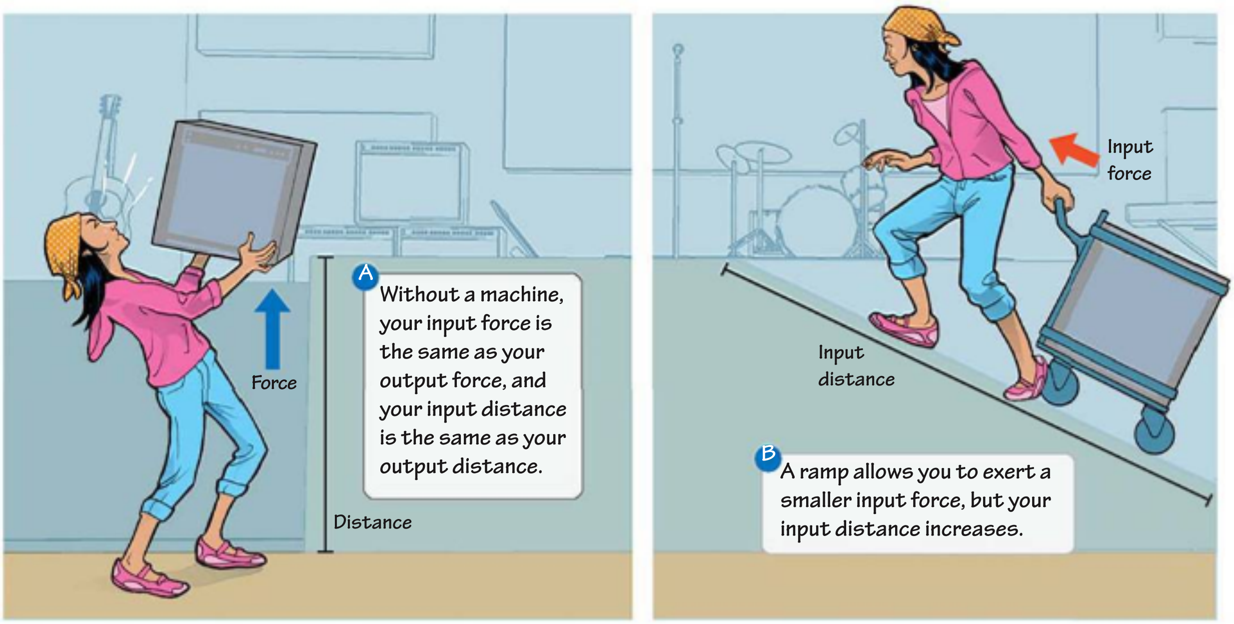
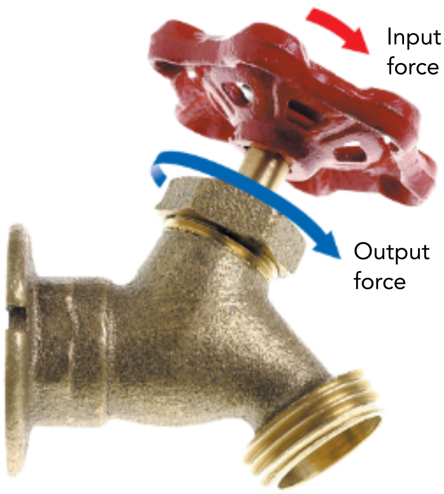
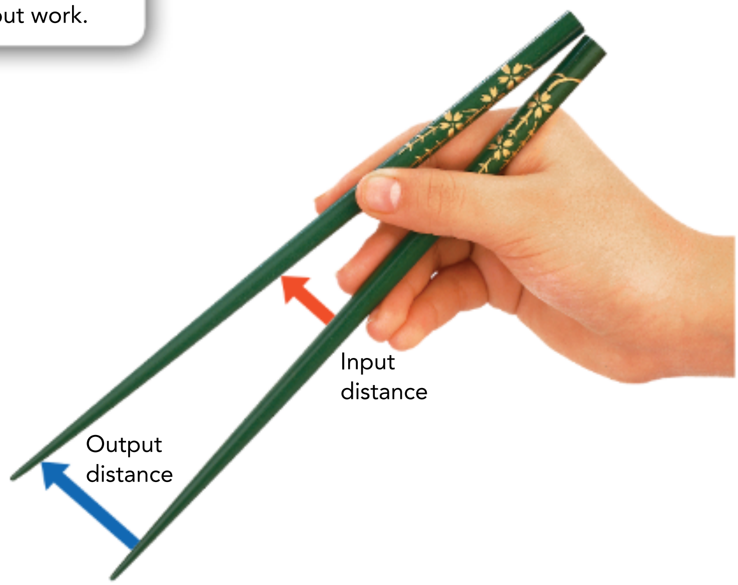


FIGURE 2

Making Work Easier

The devices shown all make work easier in different ways. The arrows on the photos show how the machines change input work.





Changing Force In some machines, the output force is *greater* than the input force. How can this happen? Recall the formula for work: Work = Force × Distance. If the amount of work stays the same, a decrease in force means an increase in distance. So if a machine allows you to use less input force to do the same amount of work, you must apply that smaller input force over a greater distance.

You see machines that work like this every day. How hard would it be to turn on a faucet that didn't have a handle? Since the handle is wider than the shaft of the faucet, your hand turns a greater distance than it would if you turned the shaft directly. Turning the handle a greater distance allows you to use less force.

Input Work		Output Work
small input force × large input distance	=	large output force × small output distance

Changing Distance In some machines, the output force is less than the input force. This kind of machine allows you to exert your input force over a shorter distance. In order to apply a force over a shorter distance, you need to apply a greater input force. When do you use this kind of machine? Think of a pair of chopsticks. When you use chopsticks to eat, you move the hand holding the chopsticks a short distance. The other end of the chopsticks moves a greater distance, allowing you to pick up and eat a large piece of food with a small movement.

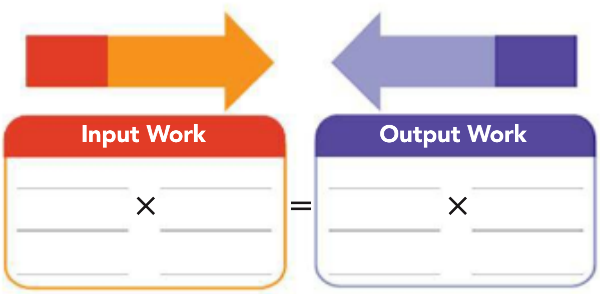
Complete the equation below. Be sure to describe each quantity as *large* or *small*.

Input Work		Output Work
______ × small input distance	=	small output force × ______

Changing Direction

Some machines don't change either force or distance. The photo above shows a machine called a *pulley* attached to a bucket. (You'll learn more about pulleys soon.) The pulley doesn't increase input force or distance. However, by changing the direction of the input force, the pulley makes it much easier to move the bucket to the top of a building—you can just pull down on the rope. Without a pulley, you would have to carry the bucket up a ladder or staircase. A flagpole rigging is also a pulley.

Complete the equation below. Be sure to describe each quantity as *large* or *small*.



Lab zone® Do the Quick Lab *Going Up.*

Assess Your Understanding

1a. List Name two examples of machines for which the output force is greater than the input force.

______

______

b. Apply Concepts Suppose that you use a pair of chopsticks and apply a force of 1 N over a distance of 0.01 m. How much work do you do? If the output force of the chopsticks is only 0.5 N, how far do the tips of the chopsticks move?

______

______

got it?

- O **I get it!** Now I know that machines make work easier by ______
- O I need extra help with ______

Go to **MY SCIENCE COACH** *online for help with this subject.*

What Is Mechanical Advantage?

You've just learned how to describe machines using words, but you can also describe machines with numbers. A machine's mechanical advantage is the number of times a machine increases a force exerted on it. **The ratio of output force to input force is the mechanical advantage of a machine.**

$$\text{Mechanical advantage} = \frac{\text{Output force}}{\text{Input force}}$$

Compare and Contrast On these two pages, underline the sentences that explain how to distinguish among machines based on their mechanical advantages.

Increasing Force When the output force is greater than the input force, the mechanical advantage of a machine is greater than 1. You exert an input force of 10 newtons on a can opener, and the opener exerts an output force of 30 newtons. The mechanical advantage of the can opener is calculated below.

$$\frac{\text{Output force}}{\text{Input force}} = \frac{30\text{ N}}{10\text{ N}} = 3$$

The can opener triples your input force!

Increasing Distance When a machine increases distance, the output force is less than the input force. The mechanical advantage is less than 1. If input force is 20 newtons and the output force is 10 newtons, the mechanical advantage is shown below.

$$\frac{\text{Output force}}{\text{Input force}} = \frac{10\text{ N}}{20\text{ N}} = 0.5$$

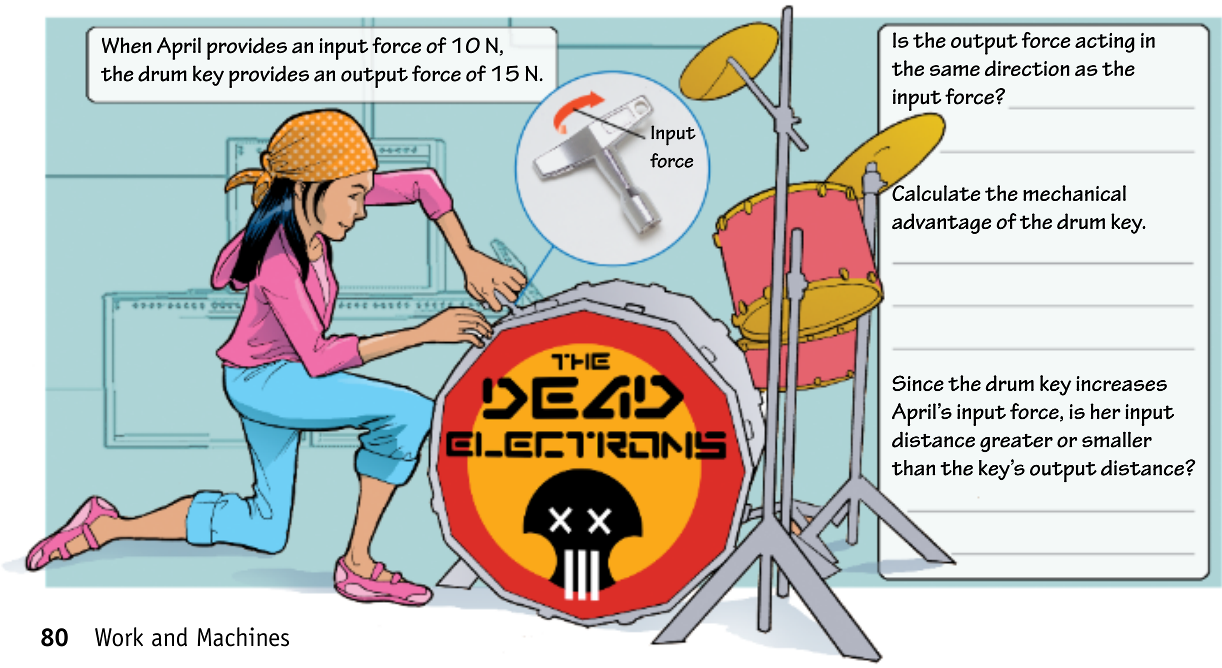
Your input force is cut in half, but your input distance is doubled.

FIGURE 3

Mechanical Advantage

Drums are tuned by tightening and loosening bolts. Drum keys make the bolts easier to turn.

Identify **Draw an arrow for the key's output force.**

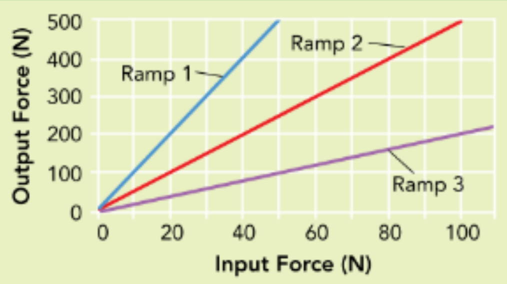


Changing Direction What can you predict about the mechanical advantage of a machine that changes the direction of the force? If only the direction changes, input force will be the same as the output force. The mechanical advantage will always be 1.

do the math!

The graph shows input and output force data for three different ramps. Use the graph to answer the questions below. (The actual ramps are not pictured. Do not confuse the lines in the graph with the ramps themselves!)

Mechanical Advantages of Ramps



1 **Read Graphs** If an 80 N input force is exerted on Ramp 2, what is the output force?

2 **Interpret Data** Find the slope of the line for each ramp.

3 **Draw Conclusions** Why does the slope represent each ramp's mechanical advantage?

4 **Graph** On the graph above, plot a line for a ramp that has a mechanical advantage of 3.

5 CHALLENGE **Predict** Which ramp is the steepest? How do you know?

Lab zone® Do the Quick Lab *Mechanical Advantage.*

Assess Your Understanding

got it?

- I get it! Now I know that mechanical advantage
- I need extra help with

Go to **my science coach** *online for help with this subject.*

What Is Efficiency?

So far you have assumed that the work you put into a machine is exactly equal to the work done by the machine. In an ideal situation, this would be true. In real situations, however, the output work is always less than the input work.

Overcoming Friction If you have ever tried to cut something with rusty scissors, you know that a large part of your work is wasted overcoming the friction between the parts of the scissors.

All machines waste some work overcoming the force of friction. The less friction there is, the closer the output work is to the input work. The **efficiency** of a machine compares output work to input work. Efficiency is expressed as a percentage. The higher the percentage, the more efficient the machine is. If you know the input work and output work for a machine, you can calculate a machine's efficiency.

Vocabulary Identify Multiple Meanings Underline the scientific definition of *efficiency* in the text. Then write a sentence that uses the everyday meaning of *efficient.*

Calculating Efficiency **To calculate the efficiency of a machine, divide the output work by the input work and multiply the result by 100 percent.** This is summarized by the following formula.

$$\text{Efficiency} = \frac{\text{Output work}}{\text{Input work}} \times 100\%$$

apply it!

1 Calculate the efficiency of this bicycle if the input work to turn the pedals is 45 J and the output work is 30 J. Show your calculations.

2 Predict What will happen to the efficiency of the bike after the gears have been cleaned and the chain has been oiled?

Real and Ideal Machines A machine with an efficiency of 100 percent would be an ideal machine. Since all machines lose work to friction, ideal machines do not exist. All machines have an efficiency of less than 100 percent.

How does this affect mechanical advantage? *Ideal* mechanical advantage is your input distance divided by the machine's output distance. It is often related to the measurements of a machine. What you have calculated so far (output force divided by input force) is *actual* mechanical advantage. If machines were ideal and input work was equal to output work, ideal and actual mechanical advantages would be equal. Because of friction, actual mechanical advantage is always less than ideal mechanical advantage.

FIGURE 4

REAL-WORLD INQUIRY

An Ideal Machine?

The balls of this Newton's cradle may swing for a long time, but they will eventually come to rest.

Communicate **With a partner, discuss where in this machine work is lost due to friction. Circle these locations on the photo and explain your reasoning.**

Lab zone Do the Quick Lab *Friction and Efficiency.*

Assess Your Understanding

2a. Relate Cause and Effect Real machines have an efficiency of less than 100% because some work is wasted to overcome ____________

b. Predict What happens to the efficiency of a bicycle as it gets rusty? What must you do to maintain the same amount of output work?

____

got it?

○ **I get it!** Now I know that efficiency ____________

____

○ **I need extra help with** ____________

Go to **my science coach** *online for help with this subject.*

LESSON 3

Inclined Planes and Levers

UNLOCK THE BIG Q

- How Do Inclined Planes Work?
- How Are Levers Classified?

my planet Diary

Is It a Machine?

Which objects in the photo below are machines? If you guessed the truck and the motorbike, you're correct—but not completely! Remember, a device doesn't have to be complicated or motorized in order to be a machine. Look between the truck and the motorbike. The ramp is a machine. Look at the person rolling the bike up the ramp. His hands hold the handlebars. His knees bend to help him walk. These are examples of simple machines. The motorbike and the truck contain many simple machines. There are dozens of machines in this photo, not just the two with motors.

MISCONCEPTIONS

Communicate Discuss these questions with a partner. Then write your answers below.

1. What kind of work is made easier by the ramp in the picture?

______

______

______

2. What are other examples of ramps that you have seen or used?

______

______

PLANET DIARY Go to **Planet Diary** to learn more about everyday machines.

Lab zone Do the Inquiry Warm-Up *Inclined Planes and Levers.*

Vocabulary
- simple machine
- inclined plane
- wedge
- screw
- lever
- fulcrum

Skills
Reading: Relate Cause and Effect
Inquiry: Infer

How Do Inclined Planes Work?

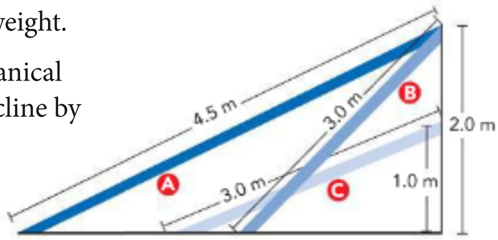
Machines can be as simple as chopsticks or as complex as motorbikes. Any complex machine can be broken down into smaller building blocks called simple machines. A **simple machine** is the most basic device for making work easier. Three closely related simple machines—the inclined plane, the wedge, and the screw—form the inclined plane family.

Inclined Plane

Lifting a heavy object such as a motorbike is much easier with a ramp. A ramp is an example of a simple machine called an inclined plane. An **inclined plane** is a flat, sloped surface.

How It Works **An inclined plane allows you to exert your input force over a longer distance.** As a result, the input force needed is less than the output force. The input force you use on an inclined plane is the force with which you push or pull an object along the slope. The inclined plane's output force is equal to the object's weight.

Mechanical Advantage You can determine the ideal mechanical advantage of an inclined plane by dividing the length of the incline by its height.



apply it!

1. Imagine you were pushing a wheelchair up the ramps in the drawing above. Which would be the hardest to use? Why?

2. Calculate the ideal mechanical advantage of each ramp using the following formula.

$$\text{Ideal mechanical advantage} = \frac{\text{Length of ramp}}{\text{Height of ramp}}$$

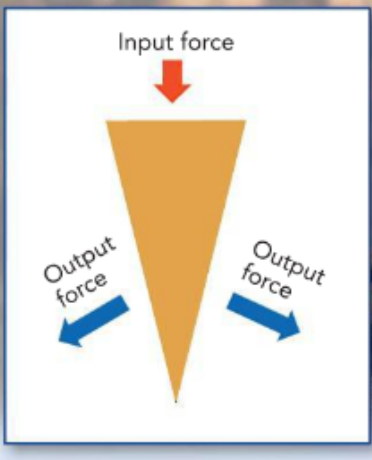
3. The ramp with the (smallest/greatest) mechanical advantage is the steepest.

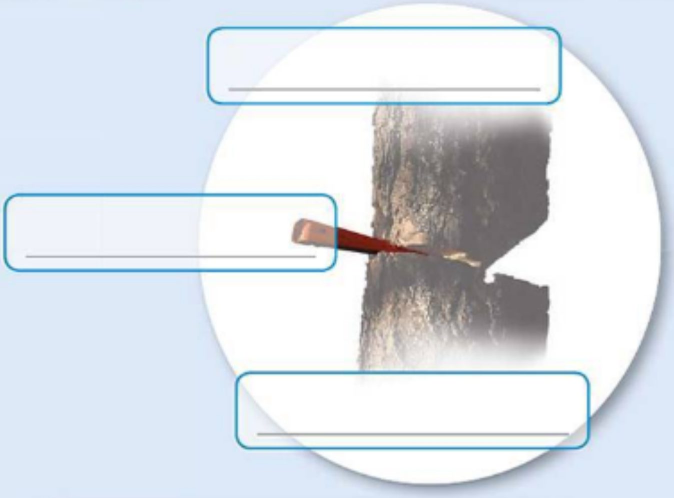
FIGURE 1

Wedges

During a forest fire, select trees are cut down to prevent the fire from spreading.

Review **In the white circle below, draw and label the input force acting on the wedge and the output forces it exerts.**





Wedge If you've ever sliced an apple with a knife or pulled up a zipper, you are familiar with another simple machine known as a wedge. A wedge is a device that is thick at one end and tapers to a thin edge at the other end.

How It Works Think of a wedge as an inclined plane (or two back-to-back inclined planes) that moves. **When you use a wedge, instead of moving an object along the inclined plane, you move the inclined plane itself.** For example, when an ax is used to split wood, the ax handle exerts a force on the blade of the ax, which is the wedge. That force pushes the wedge down into the wood. The wedge in turn exerts an output force at a 90 angle to its slope, splitting the wood in two.

Mechanical Advantage The ideal mechanical advantage of a wedge is determined by dividing the length of the wedge by its width. The longer and thinner a wedge is, the greater its mechanical advantage. When you sharpen a knife, you make the wedge thinner. This increases its mechanical advantage. That is why sharp knives cut better than dull knives.

$$\text{Ideal mechanical advantage} \quad \frac{\text{Length of wedge}}{\text{Width of wedge}}$$

Calculate the ideal mechanical advantage of the firefighter's wedge if it is 4 cm wide and 22 cm long.

Screw

Like a wedge, a screw is a simple machine that is related to the inclined plane. A screw can be thought of as an inclined plane wrapped around a cylinder.

How It Works When you twist a screw into a piece of wood, you exert an input force on the screw. **The threads of a screw act like an inclined plane to increase the distance over which you exert the input force.** As the threads of the screw turn, they exert an output force on the wood. Friction holds the screw in place. Other examples of screws include bolts, drills, and jar lids.

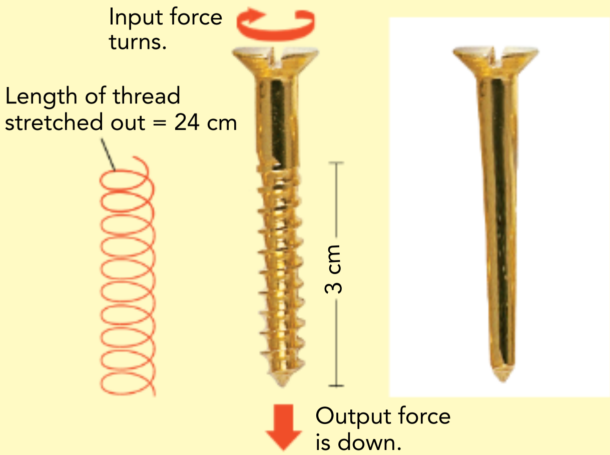
Mechanical Advantage Think of the length around the threads of a screw as the length of an inclined plane and the length of the screw as the height of an inclined plane. The ideal mechanical advantage of the screw is the length around the threads divided by the length of the screw—just as the ideal mechanical advantage of an inclined plane is its length divided by its height. The closer together the threads of a screw are, the greater the mechanical advantage.

FIGURE 2

Screws

The diagram below shows a screw with ten threads.

Calculate **What is the mechanical advantage of the screw on the left?** CHALLENGE **On the smooth screw next to it, draw in the threads to make a screw that is the same length but would be easier to screw into a piece of wood. There is a hint in the text. Find it and circle it.**



Ideal mechanical advantage $=$ $\dfrac{\text{Length around threads}}{\text{Length of screw}}$

Lab zone Do the Lab Investigation *Angling for Access.*

Assess Your Understanding

1a. List List three closely related simple machines in the inclined plane family.

b. Explain A simple inclined plane makes work easier by decreasing the input (force/distance) required to move the object.

c. Compare and Contrast Name one way inclined planes and screws are similar and one way they are different.

got it?

○ I get it! Now I know that inclined planes

○ I need extra help with

Go to MY SCIENCE COACH *online for help with this subject.*

How Are Levers Classified?

Have you ever ridden on a seesaw or used a spoon to eat your food? If so, then you are already familiar with another simple machine called a lever. A lever is a rigid bar that is free to pivot, or rotate, on a fixed point. The fixed point that a lever pivots around is called the fulcrum.

How It Works To understand how levers work, think about using a spoon. Your wrist acts as the fulcrum. The bowl of the spoon is placed near your food. When you turn your wrist, you exert an input force on the handle, and the spoon pivots on the fulcrum. As a result, the bowl of the spoon digs in, exerting an output force on your food.

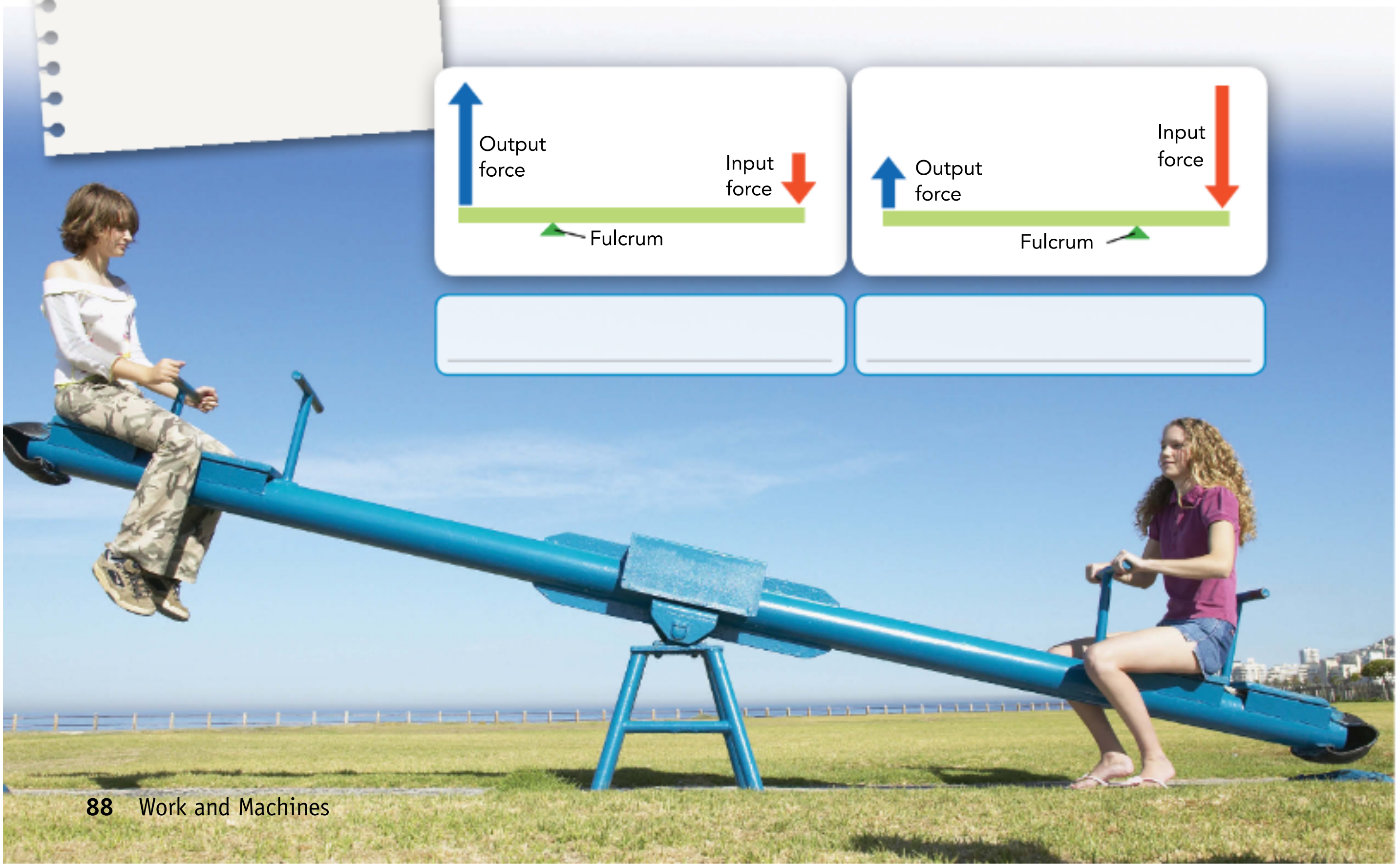
Relate Cause and Effect
The How It Works paragraph describes the use of a spoon. Underline the cause and the effect in this paragraph.

FIGURE 3

Levers

A seesaw is a type of lever in which the fulcrum is located halfway between the input and output forces.

Make Models In the space to the left, draw a diagram of a seesaw. Label the fulcrum, the input force, and the output force. CHALLENGE The diagrams below show levers in which the fulcrum is not centered. Write the name of a machine that matches each diagram.



Mechanical Advantage

Using a lever like a spoon doesn't increase your input force or change the direction of your input force. Instead, it increases your input distance. When you use a spoon, you only have to move the handle a short distance in order to scoop up food over a longer distance. However, you need to apply a greater force than you would have without the spoon.

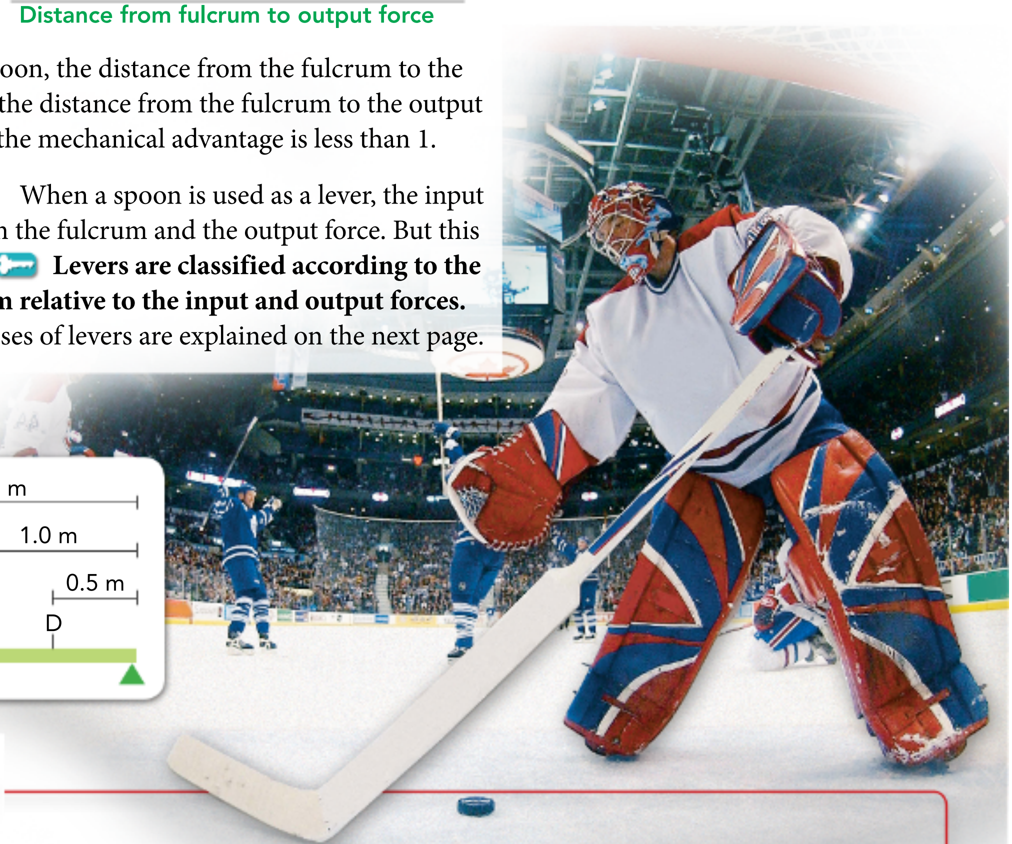
The ideal mechanical advantage of a lever is determined using the following formula.

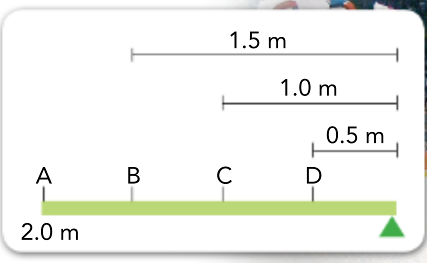
$$\text{Ideal mechanical advantage} = \frac{\text{Distance from fulcrum to input force}}{\text{Distance from fulcrum to output force}}$$

In the case of the spoon, the distance from the fulcrum to the input force is less than the distance from the fulcrum to the output force. This means that the mechanical advantage is less than 1.

Types of Levers

When a spoon is used as a lever, the input force is located between the fulcrum and the output force. But this is not always the case. **Levers are classified according to the location of the fulcrum relative to the input and output forces.** The three different classes of levers are explained on the next page.





apply it!

A hockey stick is an example of a lever. Your shoulder acts as the fulcrum of the lever. The output force is exerted where the stick hits the puck. You exert the input force where your bottom hand grips the stick. What is the mechanical advantage of a hockey stick

1. that is gripped at point D and hits the puck at point A? ______________________

2. that is gripped at point D and hits the puck at point B? ______________________

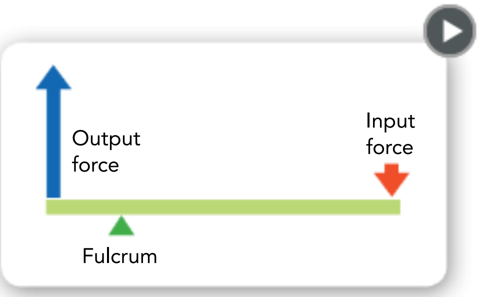
3. **Infer** Would the mechanical advantage of a hockey stick ever be greater than 1? Explain.

____
____
____
____
____

FIGURE 4

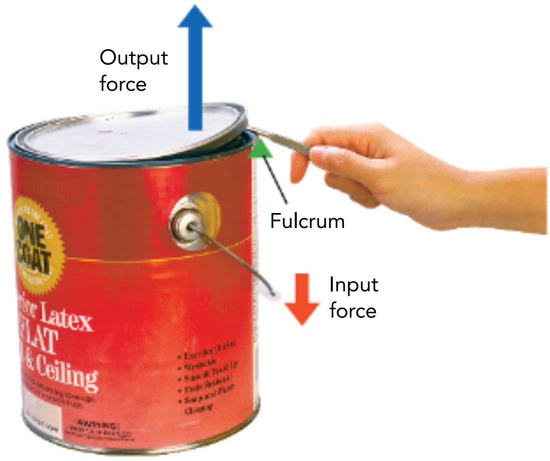
ART IN MOTION Three Classes of Levers

The three classes of levers differ in the positions of the fulcrum, input force, and output force. **Interpret Diagrams** **Draw and label the fulcrum, input force, and output force on the second-class and third-class lever photographs.**



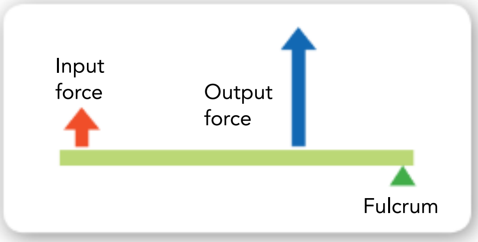
First-Class Levers

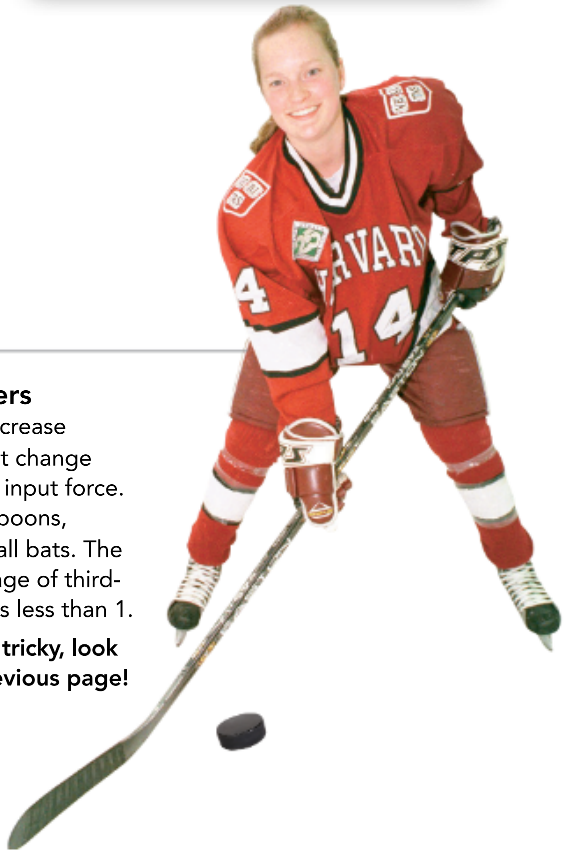
First-class levers change the direction of the input force. They also increase force or distance. Force increases if the fulcrum is closer to the output force. Distance increases if the fulcrum is closer to the input force. Examples of first-class levers include seesaws and scissors.

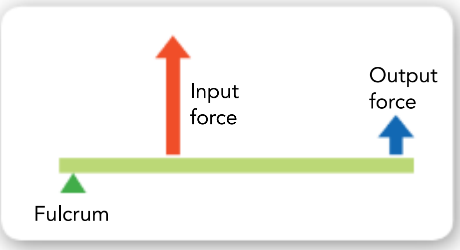


Second-Class Levers

Second-class levers increase force. They do not change the direction of the input force. Examples include doors, nutcrackers, and bottle openers. The mechanical advantage of second-class levers is always greater than 1.







Third-Class Levers

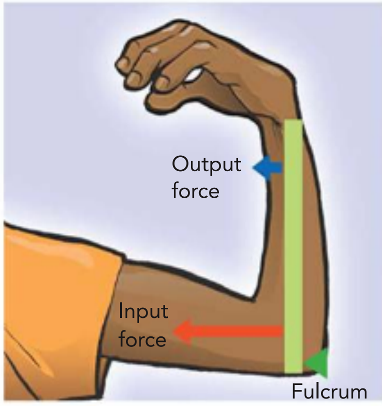
Third-class levers increase distance, but do not change the direction of the input force. Examples include spoons, shovels, and baseball bats. The mechanical advantage of third-class levers is always less than 1.

If you find this one tricky, look for help on the previous page!

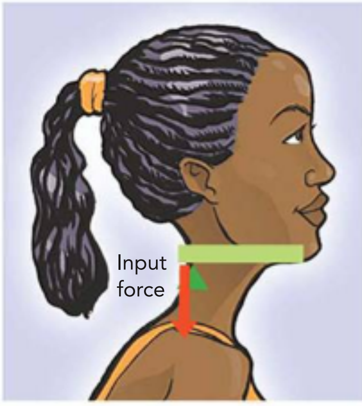
FIGURE 5

Levers in the Body

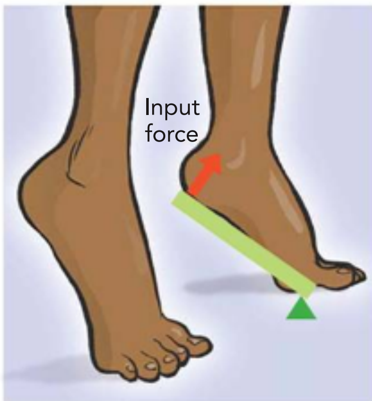
Levers can be found throughout your body. **Classify** **In the last two panels of the diagram, draw an arrow representing the output force. Then identify the class of lever for each part of the body.**



Your biceps muscle provides the input force. The output force is used to lift your arm.



The muscles in the back of your neck provide an input force, and the resulting output force tilts your chin back.



Your calf muscle provides an input force, and the resulting output force raises your body and moves it slightly forward.

Lab zone Do the Quick Lab *Modeling Levers.*

Assess Your Understanding

2a. Describe Describe how each class of lever makes work easier.

____

b. Calculate What is the mechanical advantage of lever with 2 m between the input force and the fulcrum and 1 m between the output force and the fulcrum? ________

c. Infer What class(es) of lever could the lever from the previous question be? Explain.

____

got it?

- O **I get it!** Now I know that levers are classifi ed by ________
- O I need extra help with ________

Go to MY SCIENCE COACH *online for help with this subject.*

LESSON 4

Putting Machines Together

UNLOCK THE BIG Q

- What Simple Machines Make Use of Turning?
- How Does a Compound Machine Do Work?

my planet Diary

DISCOVERY

Lidar Alert

One of the oldest forms of transportation in the world—the sailboat—may benefit from new technology: a mobile lidar station. Lidar (short for light detection and ranging) stations sense wind speed and direction using laser beams. The new station, developed by Chinese scientists, fits on a bus that can be parked near bodies of water. Sailors need to know about wind speed and direction to position their sails. With the information they gather from these new lidar stations and the simple machines they use to control their sails, sailors can greatly improve their chances of navigating safely and winning races.

Answer the questions below.

1. Why might sailboat makers incorporate simple machines into their designs?

____

____

2. What is another example of pairing advanced technology with simple machines?

____

____

____

PLANET DIARY Go to Planet Diary to learn more about boating.

Lab zone Do the Inquiry Warm-Up *Machines That Turn.*

Vocabulary
- pulley
- wheel and axle
- compound machine

Skills
- Reading: Summarize
- Inquiry: Classify

What Simple Machines Make Use of Turning?

If you have ever pulled a suitcase with wheels that were stuck, you know that it is easier to move the suitcase when the wheels can turn. **Two simple machines take advantage of turning: the pulley and the wheel and axle.**

How a Pulley Works When you raise a sail on a sailboat, you are using a pulley. A **pulley** is a simple machine made of a grooved wheel with a rope or cable wrapped around it. You use a pulley by pulling on one end of the rope. This is the input force. At the other end of the rope, the output force pulls up on the object you want to move. The grooved wheel turns. This makes it easier to move the rope than if it had just been looped over a stick. To move an object some distance, a pulley can make work easier in two ways. It can decrease the amount of input force needed to lift the object. It can also change the direction of your input force. For example, when you pull down on a flagpole rope, the flag moves up.

Summarize In one or two sentences, summarize what you have learned on this page.

FIGURE 1

Simple Machines in Sailboats

You can find many simple machines on a sailboat. Below are some diagrams of different parts of a sailboat. **Classify** **Circle the machines on the diagram that you think are pulleys.**

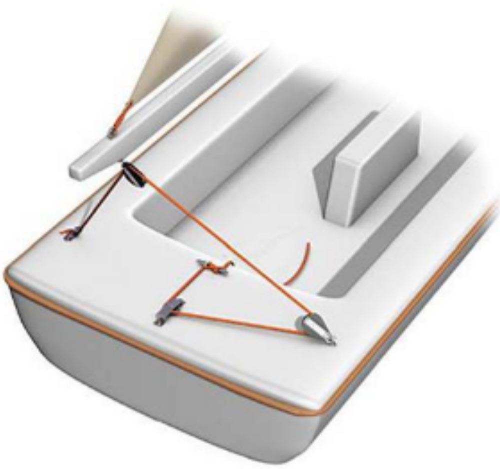
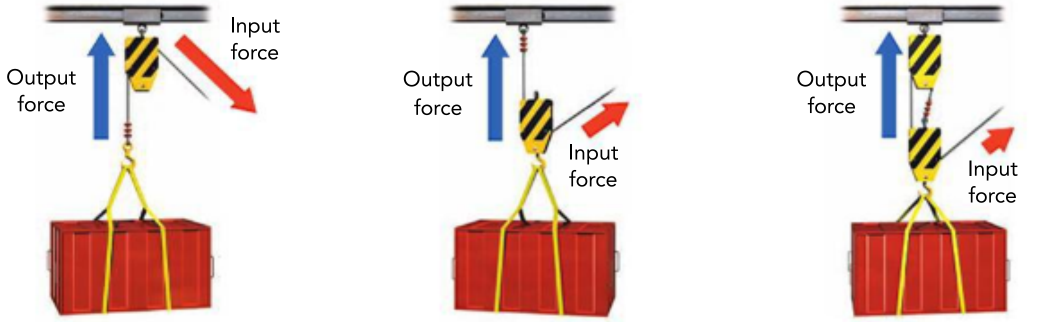


FIGURE 2

INTERACTIVE ART **Types of Pulleys**

Pulley systems are classifi ed by the number and position of the wheels they contain. Classify **Go back to Figure 1 and check your answers. Next to each pulley, label its type.**



Mechanical advantage = 1

Mechanical advantage = 2

Mechanical advantage = 3

Fixed Pulley
A fixed pulley changes the direction of force but not the amount applied.

Movable Pulley
A movable pulley decreases the amount of input force needed. It does not change the direction of the force.

Block and Tackle
A block and tackle is a pulley system made up of fixed and movable pulleys.

Types of Pulleys

A pulley that you attach to a structure is a fixed pulley. Fixed pulleys are used at the tops of flagpoles. A movable pulley is attached directly to the object you are attempting to move. Construction cranes often use movable pulleys. Combining fixed and movable pulleys makes a pulley system called a block and tackle. The direction of the input force of a block and tackle could be either up or down depending on the arrangement of the rope and pulleys. The ideal mechanical advantage of a pulley or pulley system is equal to the number of sections of rope that support the object. Don't include the rope on which you pull downward though, because it does not support the object.

apply it!

The pulley system shown here allows the painter to raise or lower herself.

1 **Label** Suppose the painter pulls down on the rope with just enough force to lift herself. Draw and label arrows to indicate the direction of the input and output forces. Draw one of the arrows longer to indicate which force is greater.

2 **Interpret Diagrams** The mechanical advantage of this pulley system is ________.

3 CHALLENGE What is the benefi t of combining fi xed and movable pulleys in a system like this one?

____

____

____

____

____

How a Wheel and Axle Works

You use a screwdriver to tighten screws because it is much easier to turn the handle instead of turning the screw itself. A simple machine made of two connected objects that rotate about a common axis is called a **wheel and axle.** The object with the larger radius is the wheel. In a screwdriver, the handle is the wheel and the shaft is the axle. When you turn the wheel, the axle rotates. The axle exerts a larger output force over a shorter distance.

If you apply force to the axle, your output force will be less than your input force. However, it will be exerted over a greater distance. This is how a paddle wheel on a boat works. The boat's motor turns an axle that turns the boat's wheel, pushing the boat forward a greater distance.

Mechanical Advantage

The ideal mechanical advantage of a wheel and axle is the radius of the wheel divided by the radius of the axle. (A radius is the distance from the outer edge of a circle to the circle's center.) The greater the ratio of the wheel radius to the axle radius, the greater the advantage.

$$\text{Ideal mechanical advantage} = \frac{\text{Radius of wheel}}{\text{Radius of axle}}$$

The blue screwdriver has a handle radius of 1.5 cm and a shaft radius of 0.25 cm. What is its mechanical advantage? ___________

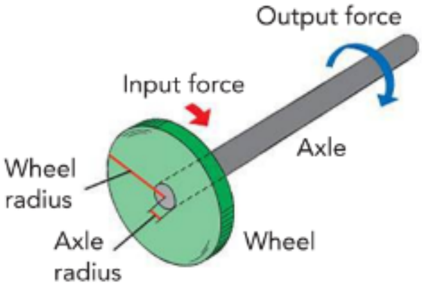
Classify Go back to Figure 1 and recheck your answers. If you spot a wheel and axle, draw a box around it.

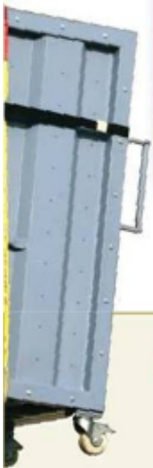
FIGURE 3

Wheel and Axle

The screwdrivers have the same shaft radius. The blue screwdriver has a larger handle radius.

Infer Circle the screwdriver with the greater mechanical advantage.





Lab zone — Do the Quick Lab *Building Pulleys.*

Assess Your Understanding

1a. List List two examples of a wheel and axle. Which of your examples has the greater mechanical advantage?

____

____

b. Apply Concepts You exert a 100-N force on a pulley system to lift 300 N. What's the mechanical advantage of this system? How many sections of rope support the weight?

____

got it?

○ I get it! Now I know that pulleys and wheels and axles ___________

____

○ I need extra help with ___________

Go to MY SCIENCE COACH *online for help with this subject.*

How Does a Compound Machine Do Work?

Suppose you and your neighbors volunteer to clean up a local park. Will the job be easier if just a few people help or if everyone in the neighborhood works together? Getting a job done is usually easier if many people work on it. Similarly, doing work can be easier if more than one simple machine is used. A machine that combines two or more simple machines is called a **compound machine.**

Within a compound machine, the output force of one simple machine becomes the input force of another simple machine. Think about a stapler. The handle is a lever. Each tip of a staple acts as a wedge. Suppose the lever has a mechanical advantage of 0.8 and the wedge has mechanical advantage of 2. If you input a force of 10 N on the lever, the output force of the lever will be 8 N. That 8 N becomes the input force of the wedge, and the final output force is 8 N times 2, or 16 N.

Recall that mechanical advantage is output force divided by input force. The mechanical advantage of the stapler is 16 N divided by 10 N, or 1.6. There is another way to calculate this value. You can multiply the mechanical advantages of the stapler's component machines, the lever (0.8) and the wedge (2). The ideal mechanical advantage of a compound machine is the product of the ideal mechanical advantages of the simple machines that it consists of.

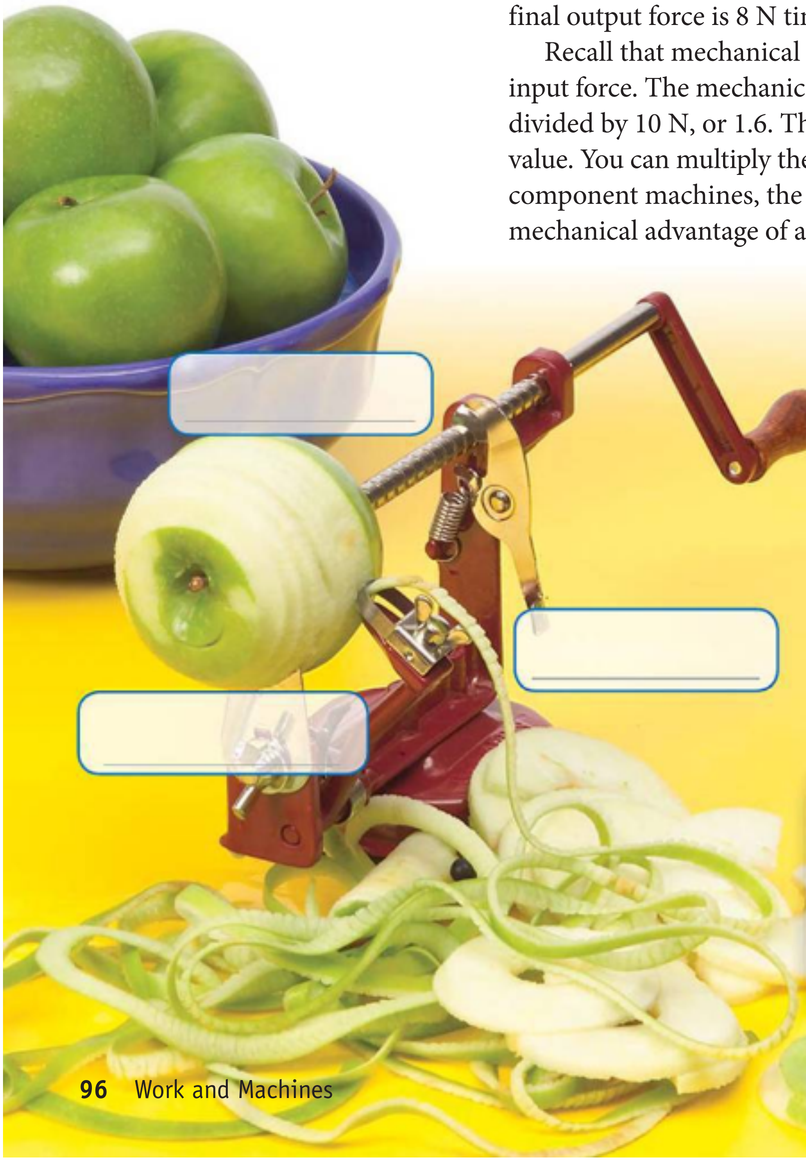


FIGURE 4

Compound Machines

A compound machine consists of two or more simple machines. **Identify In the photo at the left, circle and identify three simple machines that make up the apple peeler.**

If the mechanical advantages of the component machines in the peeler are 2, 3, and 12, what is the overall mechanical advantage of the apple peeler?

Table of Contents

LESSON 1

What Is Energy?

UNLOCK THE BIG Q

- How Are Energy, Work, and Power Related?
- What Are Two Types of Energy?

my planet Diary

Wind Farms

Did you know that wind can be used to produce electricity? A wind farm is a group of very large windmills, or turbines, placed in a location that gets a lot of wind. The energy of the wind causes the propellers of the turbines to spin. The turbines are connected to generators. When the turbines are spinning, the generators produce electricity. The amount of electricity produced depends on the size of the propellers, the number of turbines, and the strength of the wind.

FUN FACT

Write your answer to the question below.

Analyze Costs and Benefits What are some advantages and disadvantages of using wind energy to create electricity?

______

______

______

______

______

______

PLANET DIARY Go to **Planet Diary** to learn more about energy.

Lab zone® Do the Inquiry Warm-Up *How High Does a Ball Bounce?*

How Are Energy, Work, and Power Related?

Did you put a book in your backpack this morning? If so, then you did work on the book. Recall that work is done when a force moves an object. The ability to do work or cause change is called energy.

Work and Energy When you do work on an object, some of your energy is transferred to that object. You can think of work as the transfer of energy. When energy is transferred, the object upon which the work is done gains energy. Energy is measured in joules—the same units as work.

Vocabulary

- energy
- kinetic energy
- potential energy
- gravitational potential energy
- elastic potential energy

Skills

- Reading: Relate Cause and Effect
- Inquiry: Calculate

Power and Energy

You may recall that power is the rate at which work is done. **Since the transfer of energy is work, then power is the rate at which energy is transferred, or the amount of energy transferred in a unit of time.**

$$\text{Power} = \frac{\text{Energy Transferred}}{\text{Time}}$$

Different machines have different amounts of power. For example, you could use either a hand shovel or a snowblower, like the one in **Figure 1,** to remove snow from your driveway. Each transfers the same amount of energy when it moves the snow the same distance. However, you could move the snow faster using a snowblower than a hand shovel. The snowblower has more power because it transfers the same amount of energy to the snow in less time.

FIGURE 1

Power

The snowblower has more power than the person with the hand shovel.

Apply Concepts **You could use an elevator or the stairs to lift a box to the tenth floor. Which has greater power? Why?**

Lab zone Do the Lab Investigation *Can You Feel the Power?*

Assess Your Understanding

got it?

- O **I get it!** Now I know that since the transfer of energy is work, then power is ____
- O I need extra help with ____

Go to **my science coach** *online for help with this subject.*

What Are Two Types of Energy?

Moving objects, such as the vehicles shown in **Figure 2,** have one type of energy. A rock perched on the edge of a cliff or a stretched rubber band has another type of energy. **The two basic types of energy are kinetic energy and potential energy.** Whether energy is kinetic or potential depends on the motion, position, and shape of the object.

Kinetic Energy

A moving object can do work when it strikes another object and moves it. For example, a swinging hammer does work on a nail as it drives the nail into a piece of wood. The hammer has energy because it can do work. The energy an object has due to its motion is called **kinetic energy.**

Factors Affecting Kinetic Energy The kinetic energy of an object depends on both its speed and its mass. Suppose you are hit with a tennis ball that has been lightly tossed at you. It probably would not hurt much. What if you were hit with the same tennis ball traveling at a much greater speed? It would hurt! The faster an object moves, the more kinetic energy it has.

Kinetic energy also increases as mass increases. Suppose a tennis ball rolls across the ground and hits you in the foot. Compare this with getting hit in the foot with a bowling ball moving at the same speed as the tennis ball. The bowling ball is much more noticeable because it has more kinetic energy than a tennis ball. The bowling ball has more kinetic energy because it has a greater mass.

FIGURE 2

ART IN MOTION **Kinetic Energy**

The kinetic energy of an object depends on its speed and mass.

Use the diagram to answer the questions.

1. **Interpret Diagrams** List the vehicles in order of increasing kinetic energy.

____

____

____

2. **Explain** Describe another example of two objects that have different kinetic energies. Explain why their kinetic energies are different.

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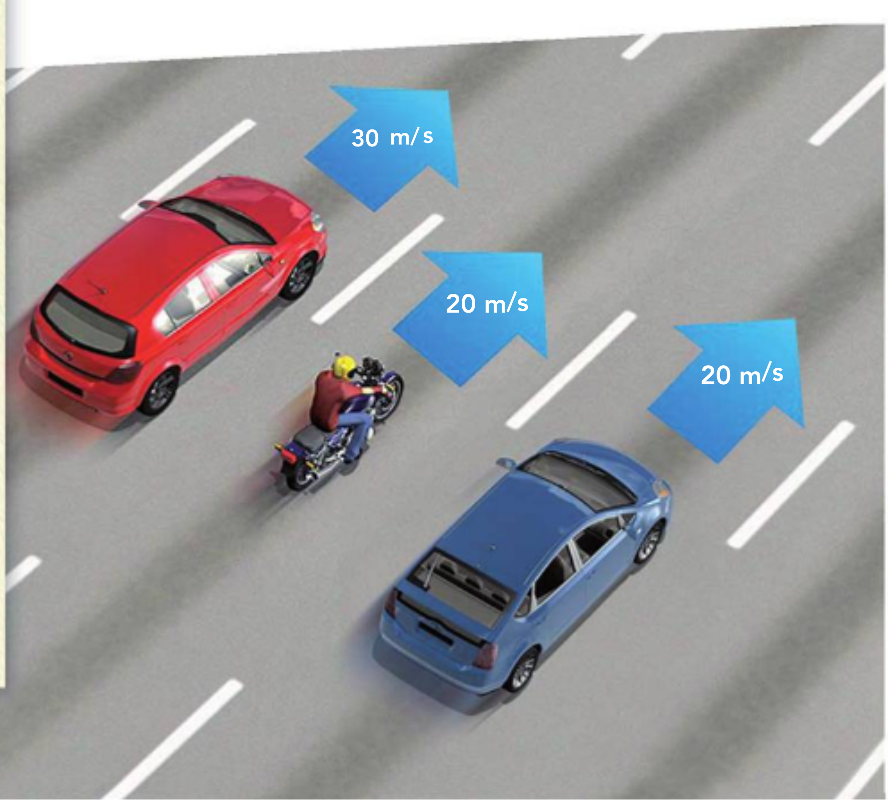

Calculating Kinetic Energy You can use the following equation to solve for the kinetic energy of an object.

$$\text{Kinetic energy} = \frac{1}{2} \times \text{Mass} \times \text{Speed}^2$$

For example, suppose a boy is pulling a 10-kg wagon at a speed of 1 m/s.

$$\text{Kinetic energy of wagon} = \frac{1}{2} \times 10\ \text{kg} \times (1\ \text{m/s})^2$$

$$= 5\ \text{kg} \cdot \text{m}^2/\text{s}^2 = 5\ \text{joules}$$

$$\text{Note that } 1\ \text{kg} \cdot \text{m}^2/\text{s}^2 = 1\ \text{joule}$$

Do changes in speed and mass have the same effect on the kinetic energy of the wagon? No—changing the speed of the wagon will have a greater effect on its kinetic energy than changing its mass by the same factor. This is because speed is squared in the kinetic energy equation. For example, doubling the mass of the wagon will double its kinetic energy. Doubling the speed of the wagon will quadruple its kinetic energy.

Relate Cause and Effect What has a greater effect on an object's kinetic energy—doubling its mass or doubling its speed? Explain.

do the math!

A girl and her dog are running. The dog has a mass of 20 kg. The girl has a mass of 60 kg.

1 **Calculate** Suppose both the dog and the girl run at a speed of 2 m/s. Calculate both of their kinetic energies.

Kinetic energy of dog =

Kinetic energy of girl =

2 **Calculate** Suppose the dog speeds up and is now running at a speed of 4 m/s. Calculate the dog's kinetic energy.

Kinetic energy of dog =

3 **Draw Conclusions** Are your answers to Questions 1 and 2 reasonable? Explain.

Review Write the SI unit for each quantity in the table.

Quantity	SI Unit
Force	________
Height	________
Work	________
Mass	________
Energy	________

Potential Energy

Potential Energy An object does not have to be moving to have energy. Some objects have energy as a result of their shapes or positions. When you lift a book up to your desk from the floor or compress a spring by winding a toy, you transfer energy to it. The energy you transfer is stored, or held in readiness. It might be used later if the book falls or the spring unwinds. Energy that results from the position or shape of an object is called **potential energy.** This type of energy has the potential to do work.

Gravitational Potential Energy Potential energy related to an object's height is called **gravitational potential energy.** The gravitational potential energy of an object is equal to the work done to lift it to that height. Remember that work is equal to force multiplied by distance. The force you use to lift the object is equal to its weight. The distance you move the object is its height above the ground. You can calculate an object's gravitational potential energy using this equation.

$$\text{Gravitational potential energy} = \text{Weight} \times \text{Height}$$

For example, suppose a book has a weight of 10 newtons (N). If the book is lifted 2 meters off the ground, the book has 10 newtons times 2 meters, or 20 joules, of gravitational potential energy.

FIGURE 3

Gravitational Potential Energy

The rock climbers have gravitational potential energy.

Use the diagram to answer the questions.

1. **Identify** Circle the rock climber with the greatest potential energy. Calculate this potential energy. The height to be used is at the rock climber's lowest foot.

____

____

____

____

____

2. **CHALLENGE** Where would the rock climbers at the top have to be to have half as much potential energy?

____

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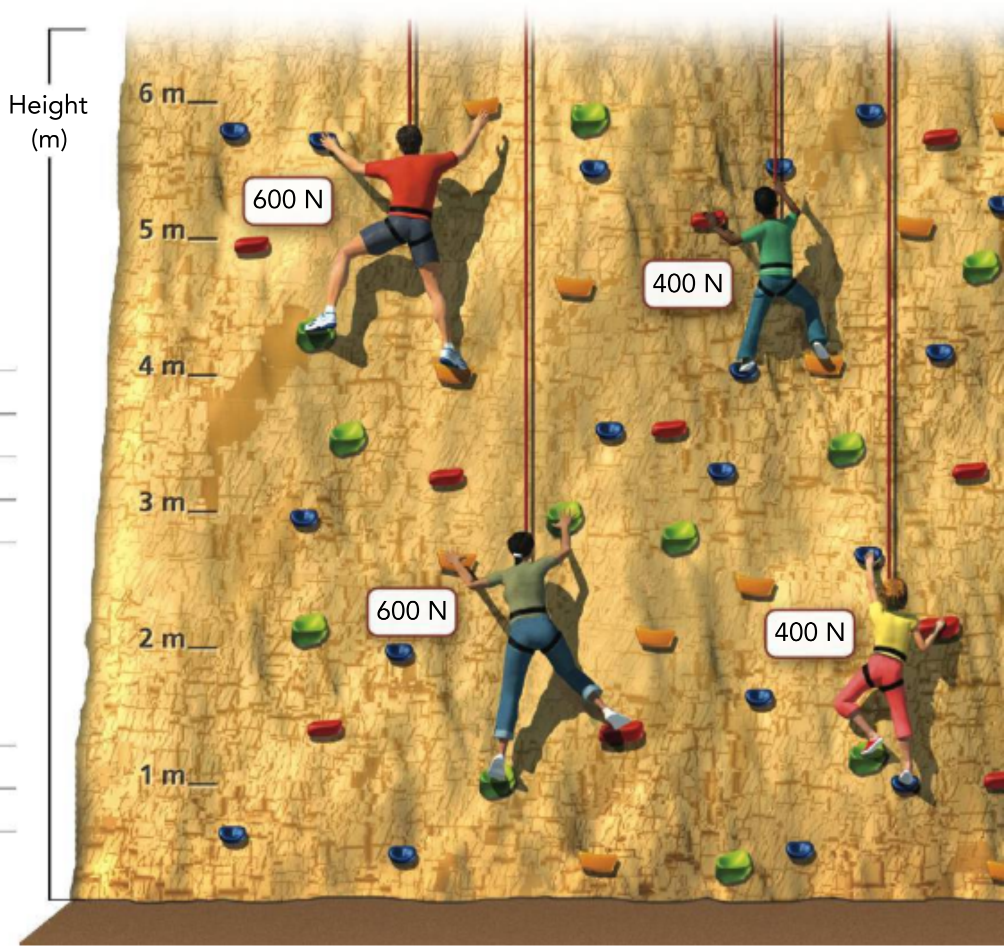


Elastic Potential Energy An object has a different type of potential energy due to its shape. **Elastic potential energy** is the energy associated with objects that can be compressed or stretched. For example, when the girl in **Figure 4** presses down on the trampoline, the trampoline changes shape. The trampoline now has potential energy. When the girl pushes off of the trampoline, the stored energy sends the girl upward.

FIGURE 4

Elastic Potential Energy

The energy stored in a stretched object, such as the trampoline, is elastic potential energy.

Interpret Diagrams **Rank the amount of elastic potential energy of the trampoline from greatest to least. A ranking of one is the greatest. Write your answers in the circles. Then explain your answers in the space to the right.**

Lab zone® Do the Quick Lab *Mass, Velocity, and Kinetic Energy*.

Assess Your Understanding

1a. Identify The energy an object has due to its motion is called (kinetic/potential) energy. Stored energy that results from the position or shape of an object is called (kinetic/potential)

b. Summarize What are the two factors that affect an object's kinetic energy?

c. Apply Concepts What type of energy does a cup sitting on a table have? Why?

got it?

○ I get it! Now I know that the two basic types of energy are

○ I need extra help with

Go to MY SCIENCE COACH *online for help with this subject.*

LESSON 2

Forms of Energy

UNLOCK THE BIG Q

- How Can You Find an Object's Mechanical Energy?
- What Are Other Forms of Energy?

my planet Diary

BLOG

Posted by: Lauren

Location: Carlisle, Massachusetts

The first hurricane that I ever saw was a big one! The storm had weakened by the time it arrived in Massachusetts, but the wind was still so powerful it easily flung around our lawn chairs. The trees bent and swayed in the wind. When it was over, branches were scattered across our lawn. The wind even ripped up a tree, blocking our road. The storm did a lot of damage, but we were lucky to be safe inside while watching this awesome force of nature.

Write your answer to the question.
What is some evidence that the storm Lauren described had energy?

PLANET DIARY Go to **Planet Diary** to learn more about forms of energy.

Lab zone® Do the Inquiry Warm-Up *What Makes a Flashlight Shine?*

How Can You Find an Object's Mechanical Energy?

What do a falling basketball, a moving car, and a trophy on a shelf all have in common? They all have mechanical energy. The form of energy associated with the motion, position, or shape of an object is called **mechanical energy.**

Vocabulary

- mechanical energy
- nuclear energy
- thermal energy
- electrical energy
- electromagnetic energy
- chemical energy

Skills

- Reading: Identify the Main Idea
- Inquiry: Classify

Calculating Mechanical Energy An object's mechanical energy is a combination of its potential energy and its kinetic energy. For example, the basketball in Figure 1 has both potential energy and kinetic energy. The higher the basketball moves, the greater its potential energy. The faster the basketball moves, the greater its kinetic energy. **You can find an object's mechanical energy by adding together the object's kinetic energy and potential energy.**

Mechanical energy = Potential energy + Kinetic energy

Sometimes an object's mechanical energy is its kinetic energy or potential energy only. A car moving along a flat road has kinetic energy only. A trophy resting on a shelf has gravitational potential energy only. But both have mechanical energy.

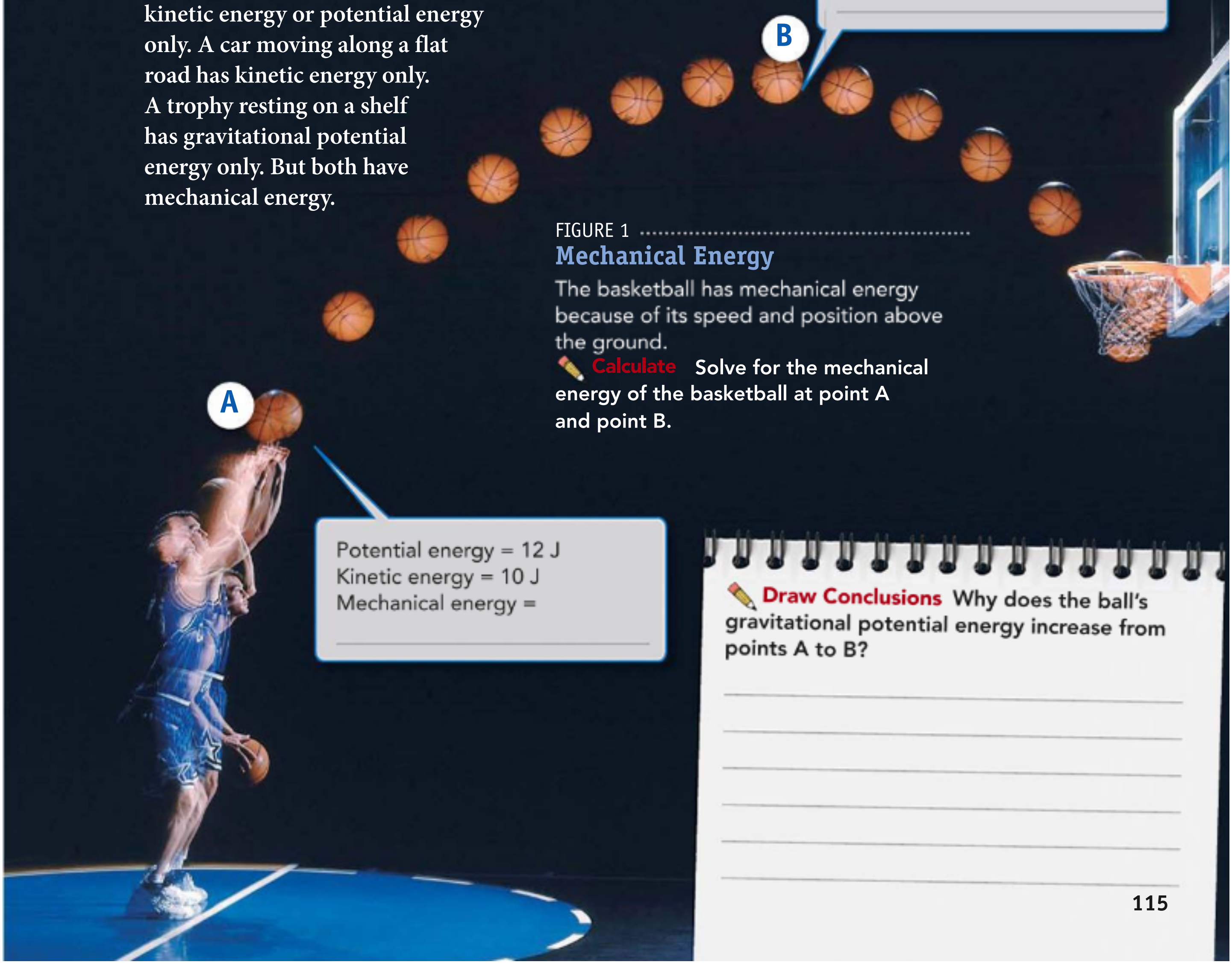
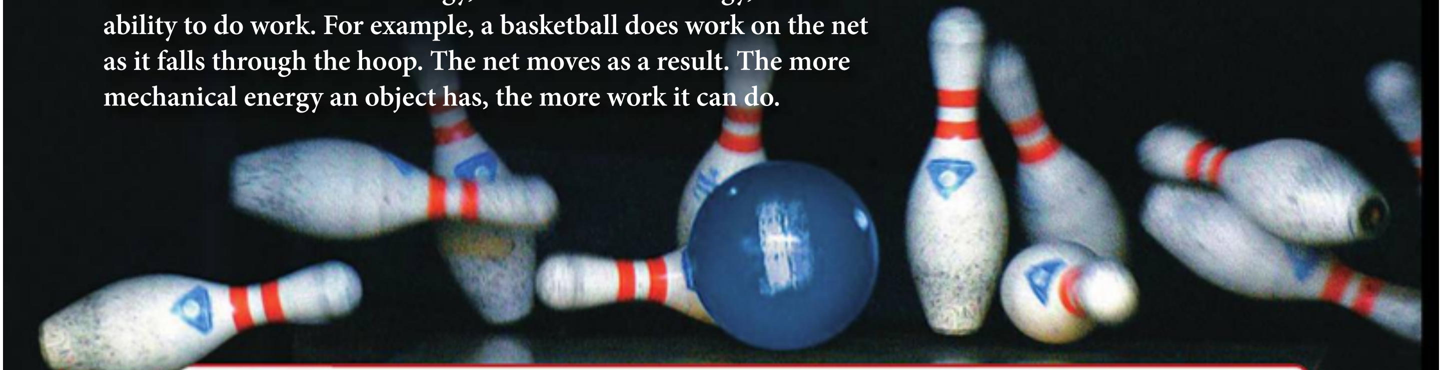


FIGURE 1
Mechanical Energy
The basketball has mechanical energy because of its speed and position above the ground.
Calculate Solve for the mechanical energy of the basketball at point A and point B.

Draw Conclusions Why does the ball's gravitational potential energy increase from points A to B?

Mechanical Energy and Work An object with mechanical energy can do work on another object. In fact, you can think of mechanical energy, like all forms of energy, as the ability to do work. For example, a basketball does work on the net as it falls through the hoop. The net moves as a result. The more mechanical energy an object has, the more work it can do.



apply it!

The bowling ball does work on the pins when it hits them.

1 Why is the bowling ball able to do work?

____

2 How should you throw the ball to maximize the amount of work it does on the pins?

____

3 CHALLENGE In the type of bowling shown in the photo, the ball has a mass of 7.0 kg. In candlepin bowling, the ball has a mass of about 1.0 kg. Does the ball with the greater mass always have the greater mechanical energy? Explain.

____

Lab zone Do the Quick Lab *Determining Mechanical Energy.*

Assess Your Understanding

1a. Define Mechanical energy is the form of energy associated with the ____________, ____________, or ____________ of an object.

b. Calculate At a certain point the kinetic energy of a falling apple is 5.2 J and its potential energy is 3.5 J. What is its mechanical energy?

____

c. Infer If an object's mechanical energy is equal to its potential energy, how much kinetic energy does the object have? Explain.

____

got it?

○ **I get it!** Now I know you can fi nd an object's mechanical energy by ____________

○ I need extra help with ____________

Go to MY SCIENCE COACH *online for help with this subject.*

What Are Other Forms of Energy?

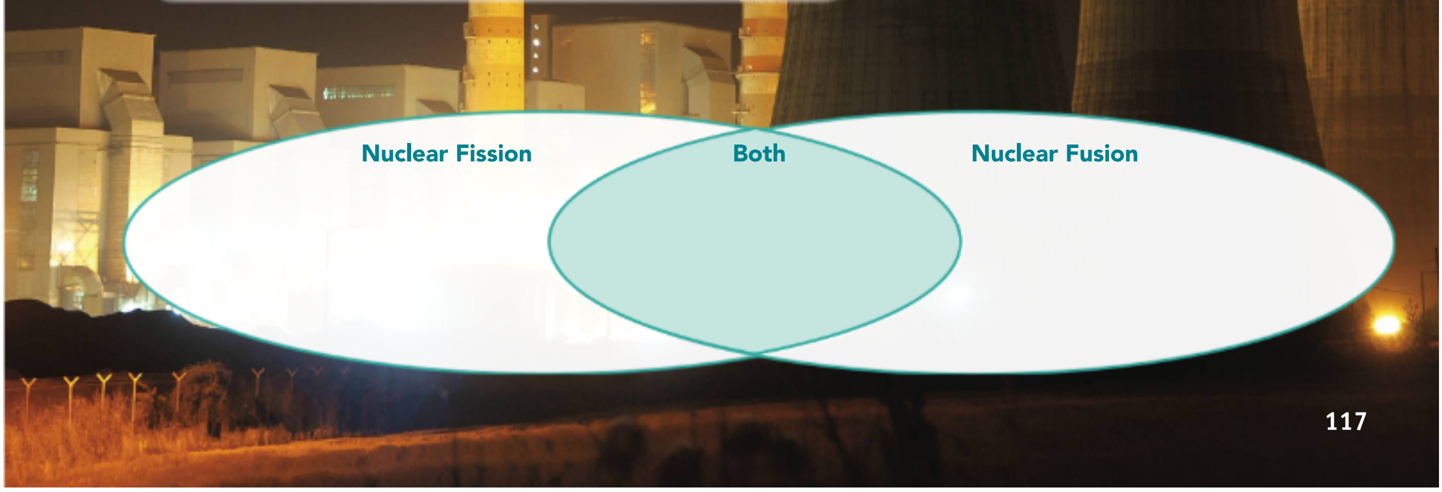
So far, you have read about energy that involves the motion, position, or shape of an object. But an object can have other forms of kinetic and potential energy. These other forms are associated with the particles that make up objects. These particles are far too small to see with the naked eye. **Forms of energy associated with the particles of objects include nuclear energy, thermal energy, electrical energy, electromagnetic energy, and chemical energy.**

Nuclear Energy All objects are made up of particles called atoms. The region in the center of an atom is called the nucleus. A type of potential energy called **nuclear energy** is stored in the nucleus of an atom. Nuclear energy is released during a nuclear reaction. One kind of nuclear reaction, known as nuclear fission, occurs when a nucleus splits. A nuclear power plant, like the one shown in **Figure 2,** uses fission reactions to produce electricity. Another kind of reaction, known as nuclear fusion, occurs when the nuclei of atoms fuse, or join together. Nuclear fusion reactions occur constantly in the sun, releasing huge amounts of energy. Only a tiny portion of this energy reaches Earth as heat and light.

Identify the Main Idea
Underline the main idea under the red heading Nuclear Energy.

FIGURE 2
Nuclear Energy
Controlled nuclear fission reactions occur at some power plants. Nuclear fusion reactions occur in the sun.

Compare and Contrast Use the Venn diagram to compare and contrast nuclear fission and nuclear fusion.



Thermal Energy

The particles that make up objects are constantly in motion. This means that they have kinetic energy. These particles are arranged in specific ways in different objects, so they also have potential energy. The total kinetic and potential energy of the particles in an object is called thermal energy.

The higher the temperature of an object, the more thermal energy the object has. For example, suppose you heat a pot of water. As heat is applied to the water, the particles in the water move faster on average. The faster the particles move, the greater their kinetic energy and the higher the temperature. Therefore, a pot of water at 75°C, for example, has more thermal energy than the same amount of water at 30°C.

Electrical Energy

When you receive a shock from a metal doorknob, you experience electrical energy. The energy of electric charges is electrical energy. Depending on whether the charges are moving or stored, electrical energy can be a form of kinetic or potential energy. Lightning is a form of electrical energy. You rely on electrical energy from batteries or electrical lines to run devices such as computers, handheld games, and digital audio players.

FIGURE 3

INTERACTIVE ART **Forms of Energy**

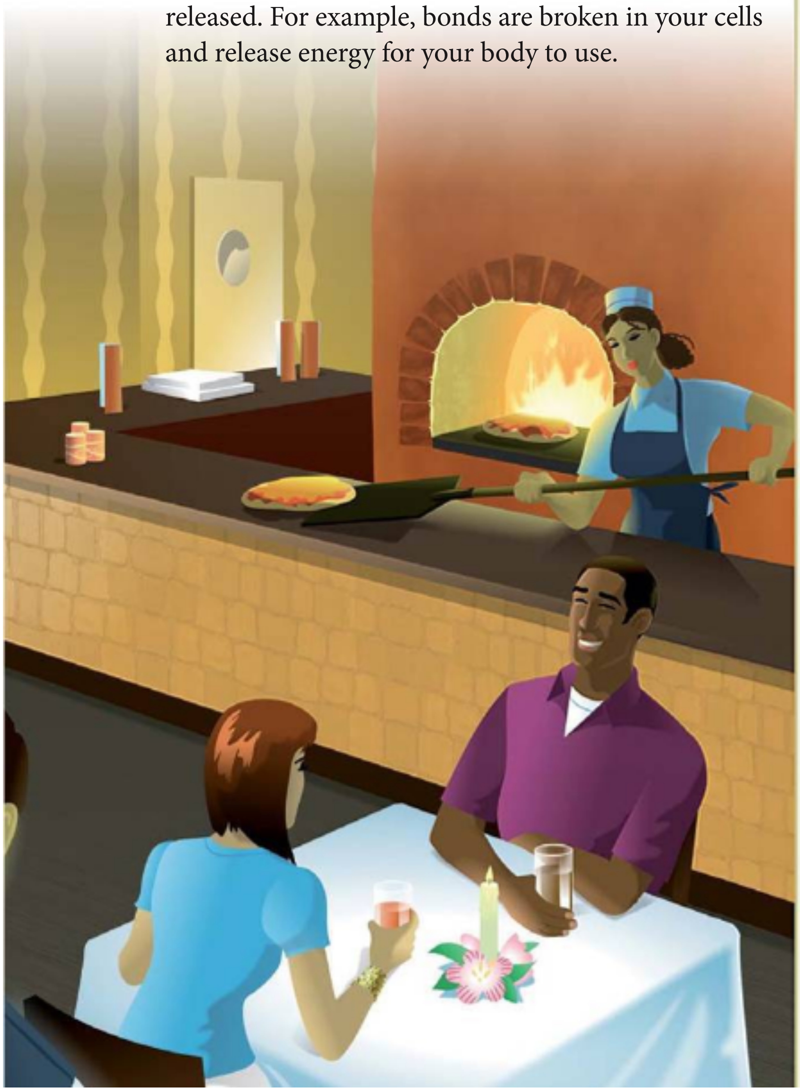
Many objects in this restaurant have more than one form of energy.

Classify **Circle three objects. Describe two forms of energy each object has.**

Electromagnetic Energy The light you see is one type of electromagnetic energy. **Electromagnetic energy** is a form of energy that travels through space in waves. The source of these waves is vibrating electric charges. These waves do not require a medium, so they can travel through a vacuum, or empty space. This is why you can see the sun and stars.

The microwaves you use to cook your food and the X-rays doctors use to examine patients are also types of electromagnetic energy. Other forms of electromagnetic energy include ultraviolet rays, infrared (or heat) waves, and radio waves. Cell phones send and receive messages using microwaves.

Chemical Energy Chemical energy is in the foods you eat, in the matches you use to light a candle, and even in the cells of your body. **Chemical energy** is potential energy stored in chemical bonds. Chemical bonds are what hold atoms together. Often when these bonds are broken, this stored energy is released. For example, bonds are broken in your cells and release energy for your body to use.



Vocabulary Identify Multiple Meanings Review the multiple meaning words in the Getting Started section and complete the sentence. During a lightning storm, electric charges move between the clouds and the ground, releasing stored

____

Lab zone Do the Quick Lab *Sources of Energy.*

Assess Your Understanding

2a. Explain Why do the particles of objects have both kinetic and potential energy?

____

____

____

____

____

____

____

b. Classify The energy you get from eating a peanut butter and jelly sandwich is in the form of ________________ energy.

got it?

○ **I get it!** Now I know the forms of energy associated with the particles of objects include ________________

____

____

____

○ I need extra help with ________________

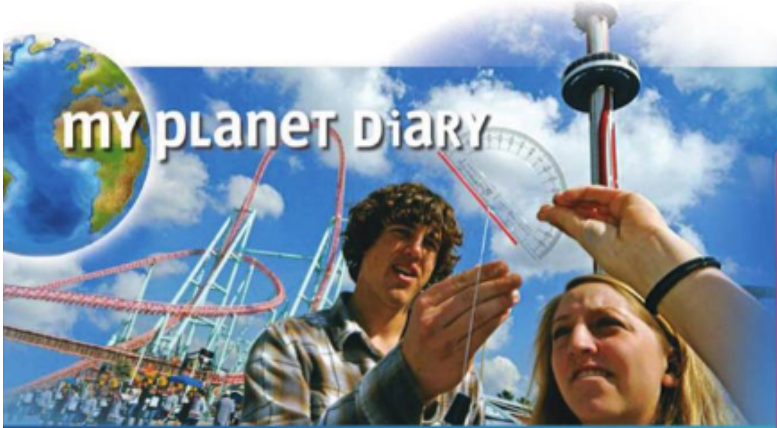
Go to **MY SCIENCE COACH** *online for help with this subject.*

LESSON 3

Energy Transformations and Conservation

UNLOCK THE BIG Q

- How Are Different Forms of Energy Related?
- What Is the Law of Conservation of Energy?



Science Day at the Amusement Park

During science days at Great America Amusement Park in Santa Clara, California, the park becomes a giant laboratory! Here is how one investigation might work. You choose a ride like the Drop Tower, which drops you 68 meters in less than four seconds, or the Fire Fall, which contains a series of vertical twists and turns. You observe how your speed and height change during the ride. Then you use your observations to learn about transformations between potential and kinetic energy.

FIELD TRIP

Write your answer to the question below.

How do you think energy is transformed in the Drop Tower?

PLANET DIARY Go to **Planet Diary** to learn more about energy transformations.

Lab zone Do the Inquiry Warm-Up *What Would Make a Card Jump?*

How Are Different Forms of Energy Related?

What does flowing water have to do with electricity? In a hydroelectric power plant, the mechanical energy of moving water is transformed into electrical energy. **All forms of energy can be transformed into other forms of energy.** A change from one form of energy to another is called an **energy transformation.** Some energy changes involve single transformations, while others involve many transformations.

Vocabulary
- energy transformation
- law of conservation of energy

Skills
- Reading: Identify Supporting Evidence
- Inquiry: Infer

Single Transformations Sometimes, one form of energy needs to be transformed into another to get work done. For example, a toaster transforms electrical energy to thermal energy to toast your bread. A cell phone transforms electrical energy to electromagnetic energy that travels to other phones.

Your body transforms the chemical energy in food to the mechanical energy you need to move your muscles. Chemical energy in food is also transformed to the thermal energy your body uses to maintain its temperature.

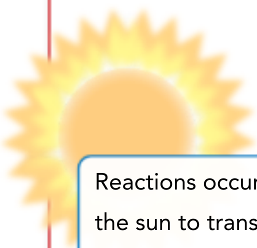
Multiple Transformations Often, a series of energy transformations is needed to do work. For example, the mechanical energy used to strike a match is transformed first to thermal energy. The thermal energy causes the particles in the match to release stored chemical energy, which is transformed to more thermal energy and to the electromagnetic energy you see as light.

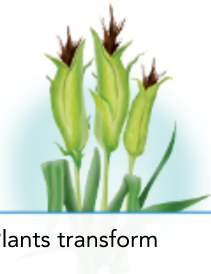
In a car engine, another series of energy conversions occurs. Electrical energy produces a spark. The thermal energy of the spark releases chemical energy in the fuel. The fuel expands as it is broken down into smaller particles. The expansion of the fuel produces pressure on parts of the car. The increased pressure eventually causes the wheels to turn, transforming chemical energy into mechanical energy.

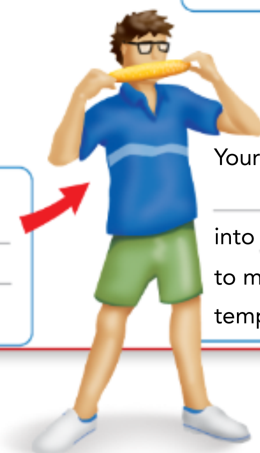
Identify Supporting Evidence
Underline the energy transformation that must occur for you to talk on your cell phone.

apply it!

A series of energy transformations must occur for you to ride your bike. Write the forms of energy involved in each transformation.







Reactions occur within the sun to transform ____________ energy into ____________ energy.

Plants transform ____________ energy into ____________ energy.

Your body transforms ____________ energy into ____________ energy to maintain your body temperature.

Your body also transforms ____________ energy into ____________ energy when you ride your bike.

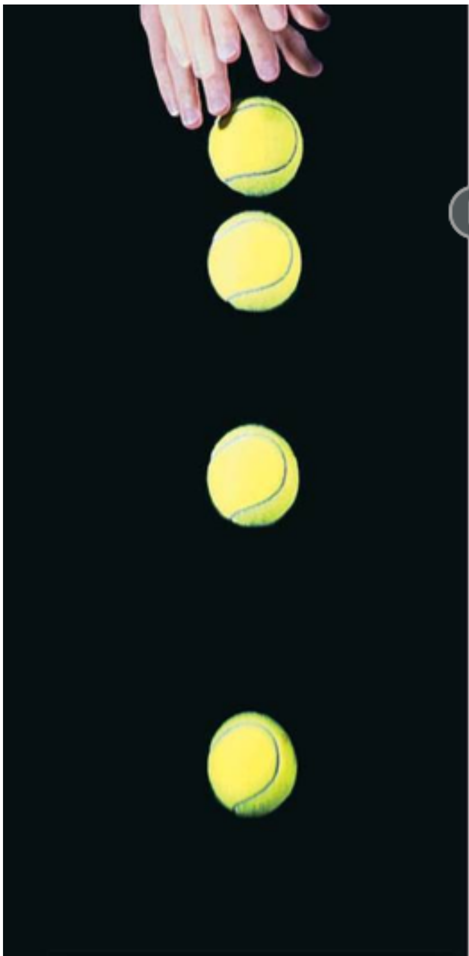


FIGURE 1

Falling Ball

The ball was photographed at equal time intervals as it fell.

Interpret Photos How can you tell that the ball's kinetic energy is increasing?

Kinetic and Potential Energy

The transformation between potential and kinetic energy is one of the most common energy transformations. For example, when you stretch a rubber band, you give it elastic potential energy. If you let it go, the rubber band flies across the room. When the rubber band is moving, it has kinetic energy. The potential energy of the stretched rubber has transformed to the kinetic energy of the moving rubber band. Transformations between kinetic and potential energy can also occur in any object that rises or falls. A falling object, a pendulum, and a pole vault are all examples of these transformations.

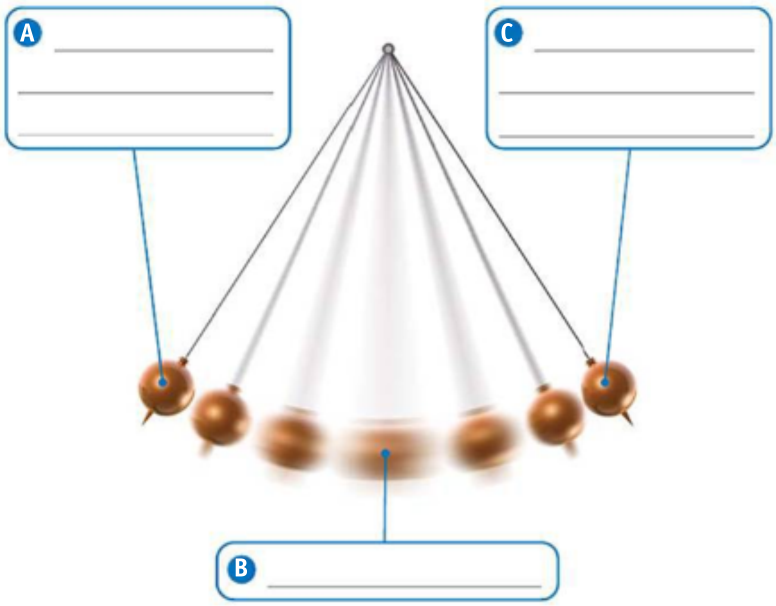
Falling Object A transformation between potential and kinetic energy occurs in the ball in **Figure 1.** As the height of the ball decreases, it loses potential energy. At the same time, its kinetic energy increases because its speed increases. Its potential energy is transformed into kinetic energy.

Pendulum A pendulum like the one in **Figure 2** swings back and forth. At the highest point in its swing, the pendulum has no movement. As it swings downward, it speeds up. The pendulum is at its greatest speed at the bottom of its swing. As the pendulum swings to the other side, its height increases and its speed decreases. At the top of its swing, it comes to a stop again.

FIGURE 2

INTERACTIVE ART **Pendulum**

A continuous transformation between potential and kinetic energy occurs in a pendulum. **Interpret Diagrams** Label the type of energy the pendulum has at positions A, B, and C.



Pole Vault The pole-vaulter in **Figure 3** starts out by running forward. When the pole-vaulter plants the pole to jump, his speed decreases and the pole bends. As the pole straightens out, the pole-vaulter is lifted high into the air. Once he is over the bar, the pole-vaulter's speed increases as he falls toward the safety cushion.

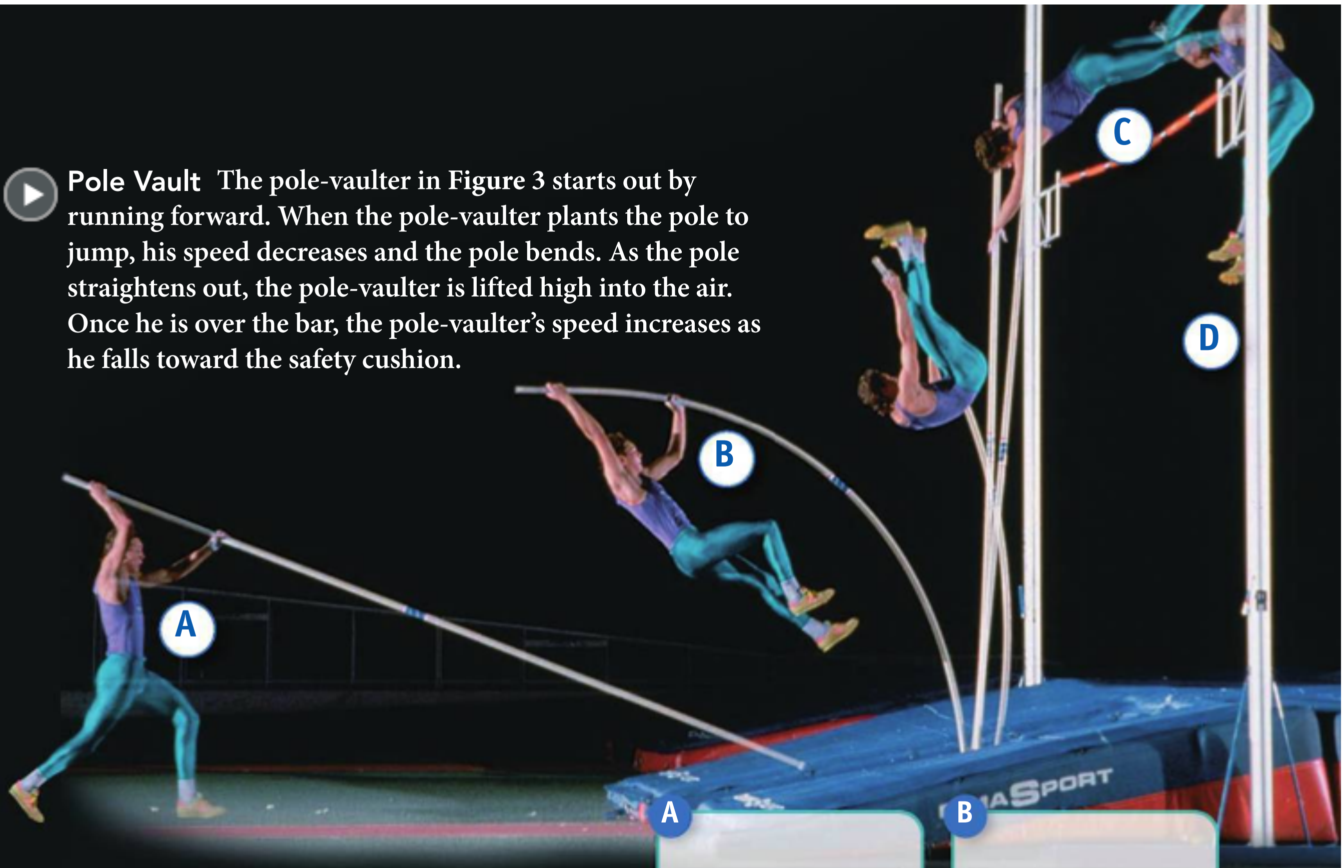


FIGURE 3

Pole Vault

Energy transformations enable this athlete to vault more than 6 meters into the air.

Sequence Identify the main forms of energy present at points A through D.

A ____________

B ____________

C ____________

D ____________

Lab zone Do the Quick Lab *Soaring Straws.*

Assess Your Understanding

1a. Define A change in one form of energy to another form of energy is called a(n) ____________

b. Relate Cause and Effect When you turn on an iron, ____________ energy is transformed into ____________ energy.

c. Apply Concepts Describe the energy transformation that occurs in a waterfall.

____

got it?

○ **I get it!** Now I know that all forms of energy can be transformed into ____________

○ I need extra help with ____________

Go to MY SCIENCE COACH *online for help with this subject.*

What Is the Law of Conservation of Energy?

Once you set a pendulum in motion, does it swing forever? No, it does not. Then what happens to its energy? Is the energy destroyed? Again, the answer is no. The **law of conservation of energy** states that when one form of energy is transformed to another, no energy is lost in the process. **According to the law of conservation of energy, energy cannot be created or destroyed.** The total amount of energy is the same before and after any transformation. If you add up all of the new forms of energy after a transformation, all of the original energy will be accounted for. So what happens to the energy of the pendulum once it stops moving?

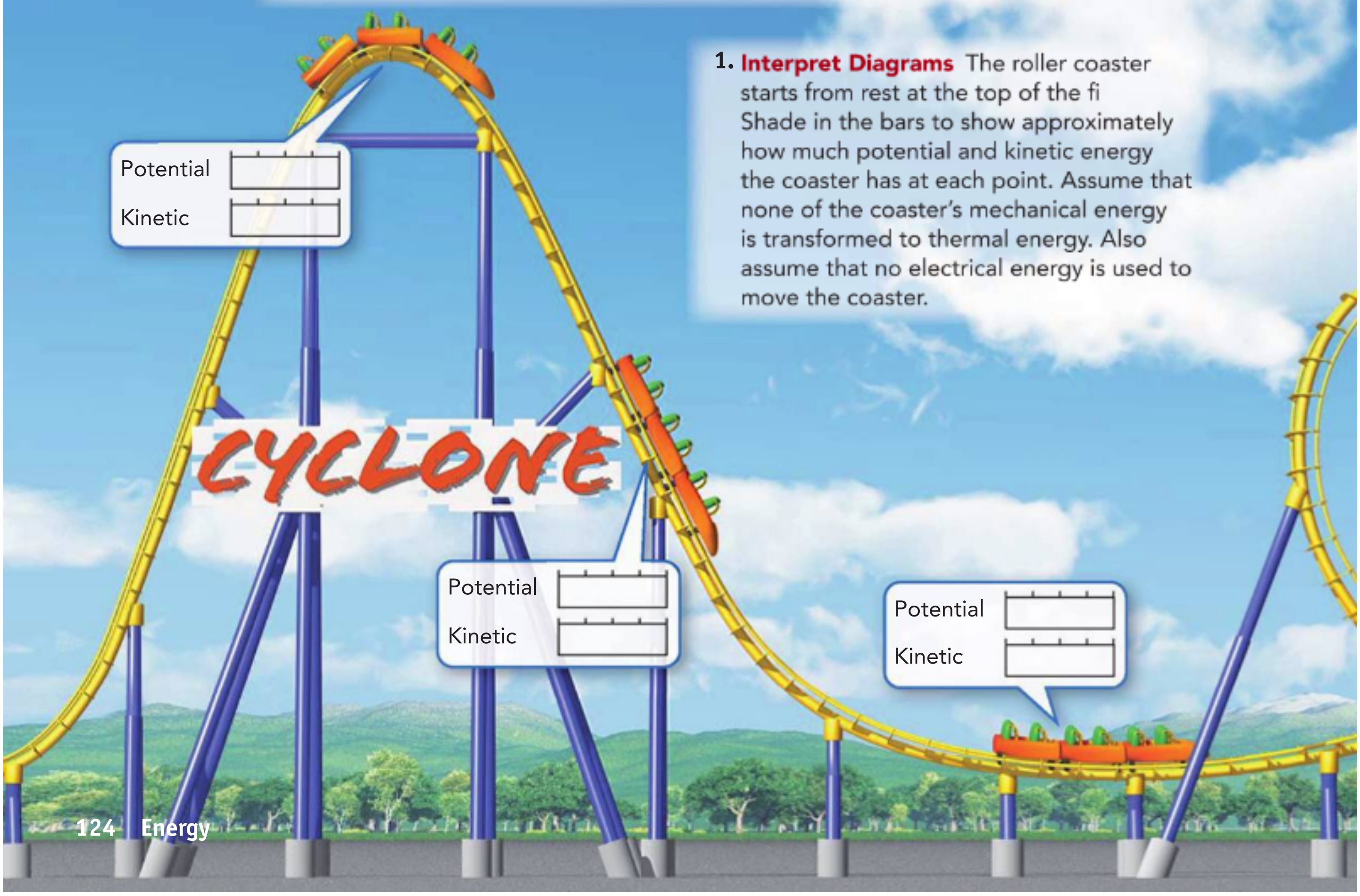
EXPLORE THE BIG Q

Conserving Energy While You Ride

How is energy conserved in a transformation?

FIGURE 4

VIRTUAL LAB Transformations between potential and kinetic energy occur during a roller coaster ride. **Use what you have learned about energy transformations to answer Questions 1–3**



1. **Interpret Diagrams** The roller coaster starts from rest at the top of the fi Shade in the bars to show approximately how much potential and kinetic energy the coaster has at each point. Assume that none of the coaster's mechanical energy is transformed to thermal energy. Also assume that no electrical energy is used to move the coaster.

As the pendulum swings, it encounters friction at the pivot of the string and from the air through which it moves. Whenever a moving object experiences friction, some of its kinetic energy is transformed into thermal energy. So the mechanical energy of the pendulum is not destroyed. It is transformed to thermal energy.

The fact that friction transforms mechanical energy to thermal energy should not surprise you. After all, you take advantage of such thermal energy when you rub your cold hands together to warm them up. Friction is also the reason why no machine is 100 percent efficient. You may recall that the output work of any real machine is always less than the input work. This reduced efficiency occurs because some mechanical energy is always transformed into thermal energy due to friction.

did you know?

When ancient animals and plants died, the chemical energy they had stored was trapped within their remains. This trapped energy is the chemical energy found in coal.

2. **Infer** Suppose you had taken thermal energy into account in Step 1. Would the total length of the shaded portion of the bars increase, decrease, or stay the same as as result?

○ Increase ○ Decrease ○ Stay the same

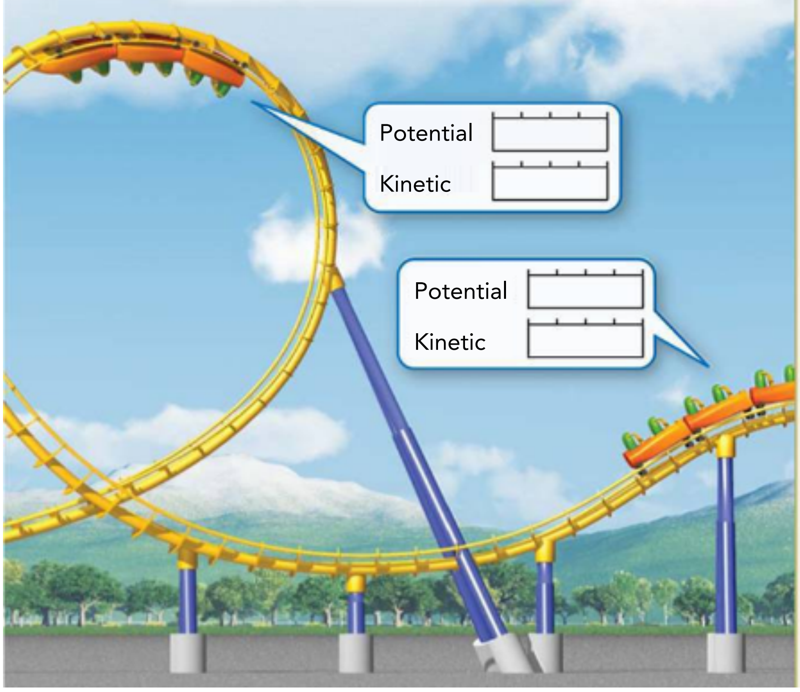
3. **CHALLENGE** Why is the first hill of a roller coaster always the tallest?

____

____

____

____



Lab zone Do the Quick Lab *Law of Conservation of Energy.*

Assess Your Understanding

2. **ANSWER THE BIG ?** How is energy conserved in a transformation?

____

____

____

____

got it?

○ I get it! Now I know that according to the law of conservation of energy, energy ______________________________

____

○ I need extra help with ______________________________

Go to **my science coach** *online for help with this subject.*

CHAPTER 4

Study Guide

The total amount of ______________________ is the same before and after any transformation.

LESSON 1 What Is Energy?

Since the transfer of energy is work, then power is the rate at which energy is transferred, or the amount of energy transferred in a unit of time.

The two basic types of energy are kinetic energy and potential energy.

Vocabulary

energy
kinetic energy
potential energy
gravitational potential energy
elastic potential energy

LESSON 2 Forms of Energy

You can fi nd an object's mechanical energy by adding together the object's kinetic energy and potential energy.

Forms of energy associated with the particles of objects include nuclear energy, thermal energy, electrical energy, electromagnetic energy, and chemical energy.

Vocabulary

mechanical energy
nuclear energy
thermal energy
electrical energy
electromagnetic energy
chemical energy

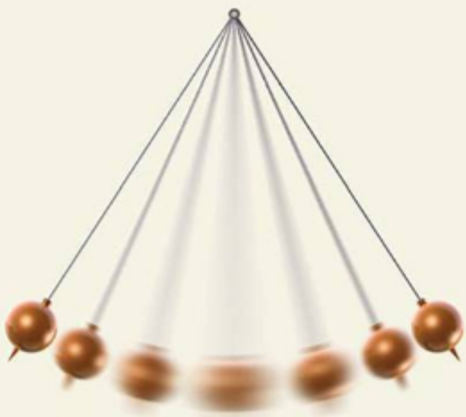
LESSON 3 Energy Transformations and Conservation

All forms of energy can be transformed into other forms of energy.

According to the law of conservation of energy, energy cannot be created or destroyed.

Vocabulary

energy transformation
law of conservation of energy



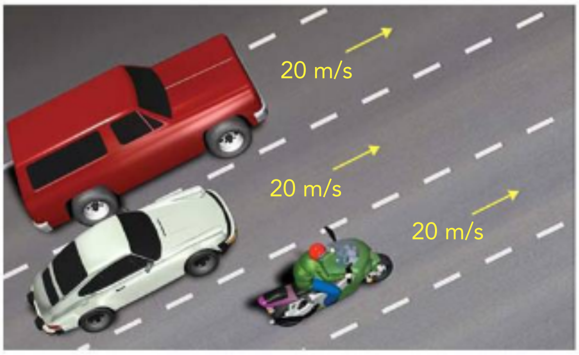
Review and Assessment

LESSON 1 What Is Energy?

1. When you stretch a rubber band, you give it
   a. kinetic energy. b. electrical energy.
   c. potential energy. d. chemical energy.

2. To calculate power, divide the amount of energy transferred by ______

3. **Compare and Contrast** In the illustration below, which vehicle has the greatest kinetic energy? Explain your answer.



4. **Apply Concepts** If a handsaw does the same amount of work on a log as a chainsaw does, which has more power? Why?

5. **math!** A 1,350-kg car travels at 12 m/s. What is its kinetic energy?

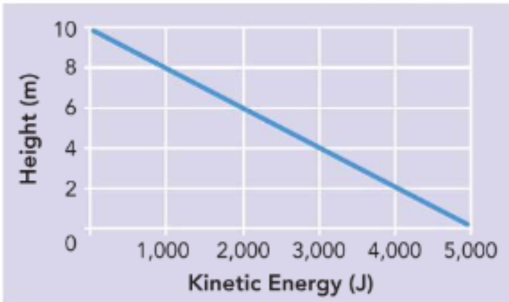
LESSON 2 Forms of Energy

6. What is the energy stored in the nucleus of an atom called?
   a. electrical energy b. chemical energy
   c. thermal energy d. nuclear energy

7. An object's mechanical energy is the sum of its ______

8. **Classify** When you heat a pot of water over a fl ame, what form of energy is added to the water?

The graph shows the kinetic energy of a 500-N diver during a dive from a 10-m platform. Use the graph to answer Questions 9 and 10.



9. **Read Graphs** How does the diver's kinetic energy change as the diver falls? Why?

10. **Calculate** What is the diver's gravitational potential energy just before the dive?

CHAPTER 4

Review and Assessment

LESSON 3 Energy Transformations and Conservation

11. As a car skids to a stop, friction transforms kinetic energy to

a. thermal energy.
b. potential energy.
c. chemical energy.
d. electrical energy.

12. The law of conservation of energy states that

13. **Classify** Describe the energy transformation that occurs in a digital clock.

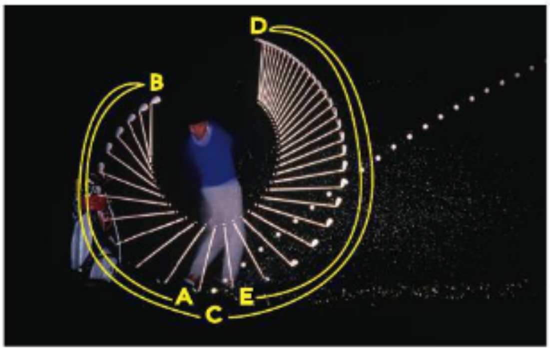
14. **Apply Concepts** Explain why a spinning top will not remain in motion forever.

15. **Infer** Why does a bouncing ball rise to a lower height with each bounce?

16. **Write About It** An eagle flies from its perch in a tree to the ground to capture and eat its prey. Describe its energy transformations.

APPLY THE BIG Q How is energy conserved in a transformation?

17. The golfer in the photo is taking a swing. The golf club starts at point A and ends at point E. (1) Describe the energy transformations of the club from points A to E. (2) The kinetic energy of the club at point C is more than the potential energy of the club at point B. Does this mean that the law of conservation of energy is violated? Why or why not?



Standardized Test Prep

Multiple Choice

Circle the letter of the best answer.

1. The table gives the kinetic and potential energy of a 6-kg cat doing various activities.

Activity	Kinetic Energy (J)	Potential Energy (J)
Running	200	0
Leaping	150	100
Climbing a tree	3	300
Sleeping on a chair	0	30

During which activity does the cat have the greatest mechanical energy?

A climbing a tree B leaping
C running D sleeping on a chair

2. Why does wind have energy?

A It can change direction.
B It can do work.
C It moves through space as waves.
D It is electrically charged.

3. What is the SI unit used to express gravitational potential energy?

A newton
B kilowatt
C horsepower
D joule

4. What causes a pendulum to eventually slow down and stop swinging?

A friction
B kinetic energy
C weight
D potential energy

5. Which energy transformation takes place when wood is burned?

A Nuclear energy is transformed to thermal energy.
B Thermal energy is transformed to electrical energy.
C Chemical energy is transformed to thermal energy.
D Mechanical energy is transformed to thermal energy.

Constructed Response

Use the table below to answer Question 6. Write your answer on a separate sheet of paper.

Time	Speed at Bottom of Swing (m/s)
8:00 a.m.	2.2
10:00 a.m.	1.9
12:00 p.m.	1.7
2:00 p.m.	1.6

6. A large pendulum at a science museum is set in motion at the beginning of the day. The table shows how its speed at the bottom of the swing changes during the day. Use this data to determine how the height of the pendulum's swing changes. Explain your answer.

SCIENCE MATTERS

Museum of Science TECH & DESIGN

CHARGE IT!

The inside of this rechargeable battery has three long thin layers. A separator separates a positive electrode from a negative electrode. Using the battery causes lithium ions to move from the positive material to the negative one. Applying an electrical charge moves the ions back to the positive electrode.

Have you ever noticed how many batteries you use every day? There are batteries in cars, flashlights, cell phones, laptop computers, and even bug zappers! Discarded batteries add up to a lot of waste. Fortunately, rechargeable batteries can help keep the energy flowing and reduce the number of batteries that get thrown out. Can you imagine how many nonrechargeable batteries a cell phone would go through in a month?

Batteries transform chemical energy into electrical energy. To refuel a rechargeable battery, you plug it into a power source—such as an outlet in the wall. The electrical energy reverses the chemical changes, storing the electrical energy as chemical energy. The battery is once again "charged up" and ready to go!

Research It Gasoline-powered cars and hybrid cars have rechargeable batteries. Research how the batteries in gasoline-powered cars and hybrid cars are recharged.

Museum of Science.

CATCH AND NO RELEASE

A spider's web is more than just a sticky net hanging across an open space. The strong, elastic nature of spider silk ensures that an insect cannot leave once it strikes the web. To make their webs, spiders produce two kinds of silk—dragline silk and capture-spiral silk.

Dragline silk makes up the web's large frame. When an insect crashes into a spider's web, the dragline silk absorbs the force of impact and spreads it out over the entire area of the frame. No matter the mass or speed of the insect, the dragline silk is strong enough to absorb the force.

Capture-spiral silk is the sticky silk at the center of the web. It is more elastic than dragline silk so it stretches and then returns to its shape when an insect strikes it. As it stretches, it transforms the insect's kinetic energy into elastic potential energy. As a result, the insect slows down gradually and doesn't immediately bounce off the web. Once the insect comes to a stop, the stickiness of the capture-spiral thread keeps the prey from leaving.

Spider silk is only one-tenth the diameter of human hair, but it is very strong. In fact, a thread of spider silk can resist more force than a piece of steel of the same size. Think of that next time you get tangled up in a spider's web.

Research It Identify an object that could be made from spider silk instead of steel or Kevlar. Then write a proposal that includes a list of spider silk's advantages and a request for funding to build a prototype of the object.

Chapter 4 Review and Assessment Key

Review and Assessment

LESSON 1 What Is Energy?

1. When you stretch a rubber band, you give it
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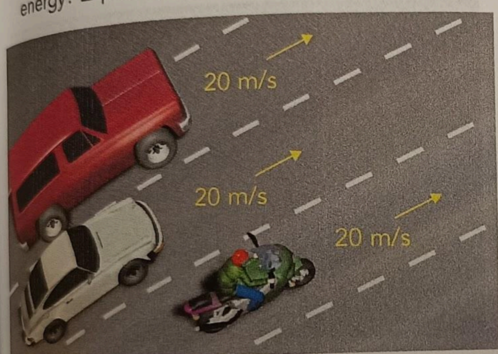
   b. electrical energy.
   c. potential energy.
   d. chemical energy.

2. To calculate power, divide the amount of energy transferred by time.

3. **Compare and Contrast** In the illustration below, which vehicle has the greatest kinetic energy? Explain your answer.



The red vehicle has the greatest kinetic energy because it has the greatest mass.

4. **Apply Concepts** If a handsaw does the same amount of work on a log as a chainsaw does, which has more power? Why?

The chainsaw has more power because it transfers the same amount of energy to the log in less time than the handsaw does.

5. **math!** A 1,350-kg car travels at 12 m/s. What is its kinetic energy?

Kinetic energy $= 1/2 \times m \times v^2$
$= (1/2) \times (1{,}350\text{ kg}) \times (12\text{ m/s})^2 = 97{,}200\text{ J}$

LESSON 2 Forms of Energy

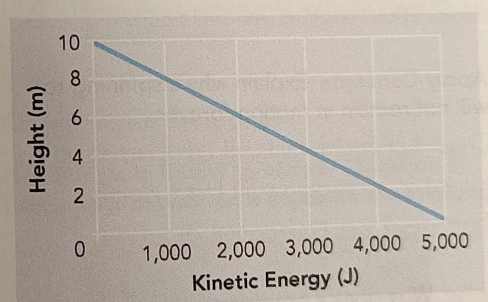
6. What is the energy stored in the nucleus of an atom called?
   a. electrical energy
   b. chemical energy
   c. thermal energy
   d. nuclear energy

7. An object's mechanical energy is the sum of its kinetic and potential energy.

8. **Classify** When you heat a pot of water over a flame, what form of energy is added to the water?

thermal energy

The graph shows the kinetic energy of a 500-N diver during a dive from a 10-m platform. Use the graph to answer Questions 9 and 10.



9. **Read Graphs** How does the diver's kinetic energy change as the diver falls? Why?

The diver's kinetic energy increases because the diver's speed increases.

10. **Calculate** What is the diver's gravitational potential energy just before the dive?

Gravitational potential energy $= \text{Weight} \times \text{Height}$
$= 500\text{ N} \times 10\text{ m} = 5{,}000\text{ J}$

CHAPTER 4

Review and Assessment

LESSON 3 Energy Transformations and Conservation

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when one form of energy is transformed to another, no energy is created or destroyed in the process.

13. **Classify** Describe the energy transformation that occurs in a digital clock.
A digital clock transforms electrical energy to electromagnetic energy.

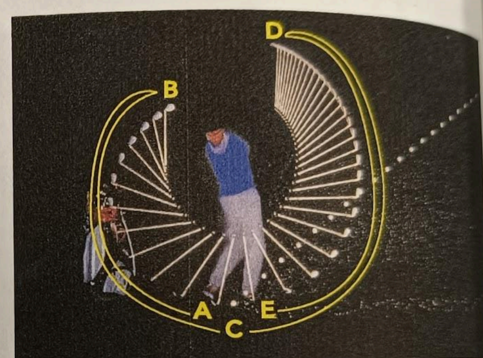
14. **Apply Concepts** Explain why a spinning top will not remain in motion forever.
Due to friction, all of the top's kinetic energy will be transformed to thermal energy.

15. **Infer** Why does a bouncing ball rise to a lower height with each bounce?
Friction between the ball and the ground, and between the ball and the air transforms mechanical energy into thermal energy. Each bounce has less mechanical energy.

16. **Write About It** An eagle flies from its perch in a tree to the ground to capture and eat its prey. Describe its energy transformations.
See TE rubric.

APPLY THE BIG ? How is energy conserved in a transformation?

17. The golfer in the photo is taking a swing. The golf club starts at point A and ends at point E. (1) Describe the energy transformations of the club from points A to E. (2) The kinetic energy of the club at point C is more than the potential energy of the club at point B. Does this mean that the law of conservation of energy is violated? Why or why not?



(1) At A, when the club is at rest, the club has no potential or kinetic energy. At B, it has near maximum gravitational potential energy and no kinetic energy. At C, it has maximum kinetic energy and no potential energy. At D, it has maximum potential energy and no kinetic energy. At E, when it is brought back to rest, it has no potential or kinetic energy. (2) The man adds energy as he swings the club. Therefore, energy is conserved.
See TE rubric.

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